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THE MARCH SCIENTIFIC MONTHLY

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THE SCIENTIFIC MONTHLY

MARCH, 1938

CORE SAMPLES OF THE OCEAN BOTTOM AND THEIR SIGNIFICANCE

By Dr. CHARLES SNOWDEN PIGGOT

GEOPHYSICAL LABORATORY, CARNEGIE INSTITUTION OF WASHINGTON

Foreword

Several years ago I determined the radium in a number of ocean-bottom samples, secured during the last cruise of the non-magnetic ship *Carnegie*, by means of the "telegraph snapper." These samples contained several times as much radium as the rocks with which I was then working, and I became interested in whether or not this radium concentration continued below the surface. This led to the development of the apparatus illustrated here, whose principle of operation, as compared with that of the telegraph snapper, is shown in Fig. 1. The telegraph snapper merely takes a small bite out of the surface of the bottom, and destroys the stratification in so doing. This apparatus drives a tube through many strata and brings up a sample whose parts remain in their original relation with respect to one another.

Introduction

Nearly three quarters of the surface of the earth has remained almost unknown and unstudied, because it lies below great depths of water. At one place the water is six miles deep, and here the bottom lies below us deeper in the sea than Mount Everest rises above us into the sky. Though much of what is now dry land was once below the surface of the ocean, it appears that the water covering it was never very deep. Though the visible sediments themselves may be many thousands of feet thick they were deposited on the sinking floors of shallow seas. Apparently, much of the bottom of the ocean has always been ocean bottom, and during all the millions of years that the ocean has existed, the floors of the deeps as well as the shallows have been accumulating sediments dropped upon them through the waters above. These sediments, lying layer upon layer in the bottom, have become the repository of the historical record of the ocean. This record includes the contributions of the rivers, reflecting the changing conditions on the continents, as well as those of ice and wind and the myriad life in the water above. The record of what happened in this water above is filed away in the mud and clay and ooze below. The rocks and pebbles and sand brought by ice, the clay and mud brought by rivers and ocean currents, the skeletons of marine organisms which lived and died and evolved into various forms throughout the ages constitute this record. Some types of these organisms live only in cold water, others in warm water, some live in shallow lagoons, others in the depths of the open sea. Some prefer fresh water, while others survive only in salty water. Some

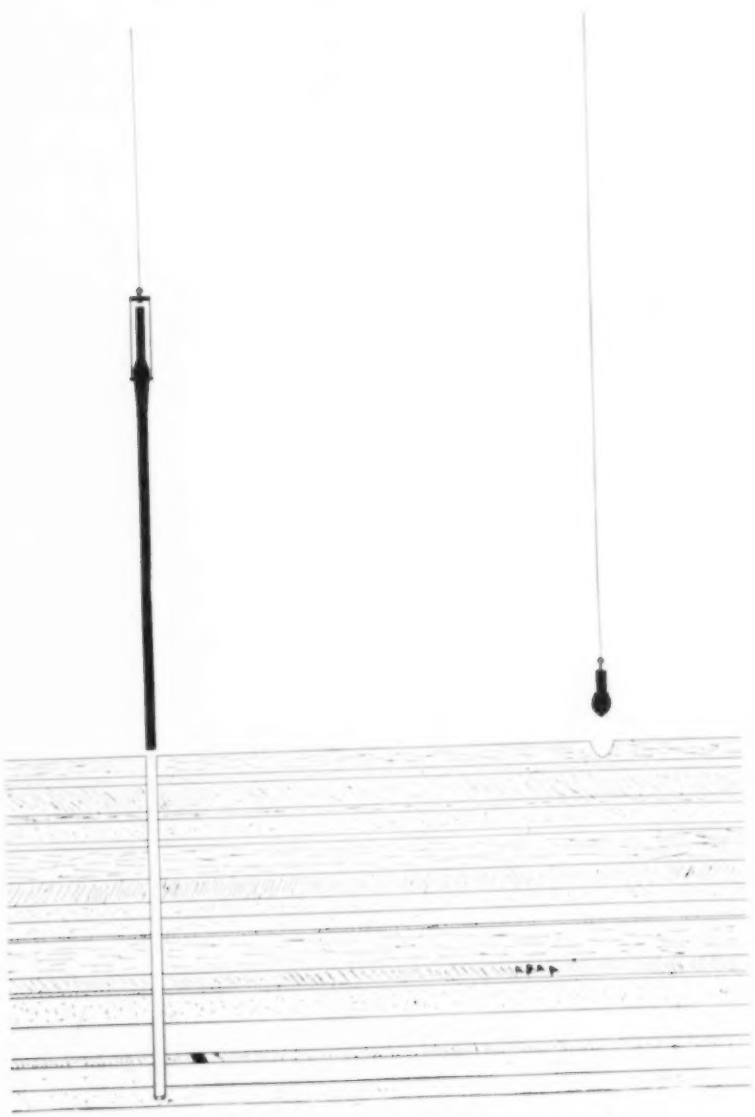


FIG. 1. COMPARISON OF SNAPPER WITH CORE SAMPLER.

lived a long time ago, and others have evolved into their present forms comparatively recently. In addition to these records of life and its many changes there exists a chemical and a physical record. Oxidation and reduction and the nature of the dissolved matter in the water have all left the record of their changes in the bottom, and the nature and size of the minerals and rock fragments bear evidence of the direction and strength of former ocean currents, the movements of ice and the depths of the ocean in the past.

Heretofore, the samples obtained from the deep ocean bottom have been a mere handful of material taken from the very surface of the bottom. These samples give information of present conditions only and reveal nothing of past events.

so that although the historical record has been known to exist we have been able to see only the topmost page.

On land the geologist studies the exposed rock strata, but a study of material lying beneath miles of water is enormously more difficult. If, however, we could bring up a vertical section of several feet of this bottom, in its original, undisturbed condition, we might read the history of oceanic events as the geologist deciphers the record in the rocks.

The need for such samples has been apparent for many years, and many attempts to secure them have been tried, but although the bottom of the ocean has long been an object of interest, its remoteness and inaccessibility have kept it literally a terra incognita.

Historical

Let us consider briefly the historical development of oceanic investigation. The traditional method of ascertaining

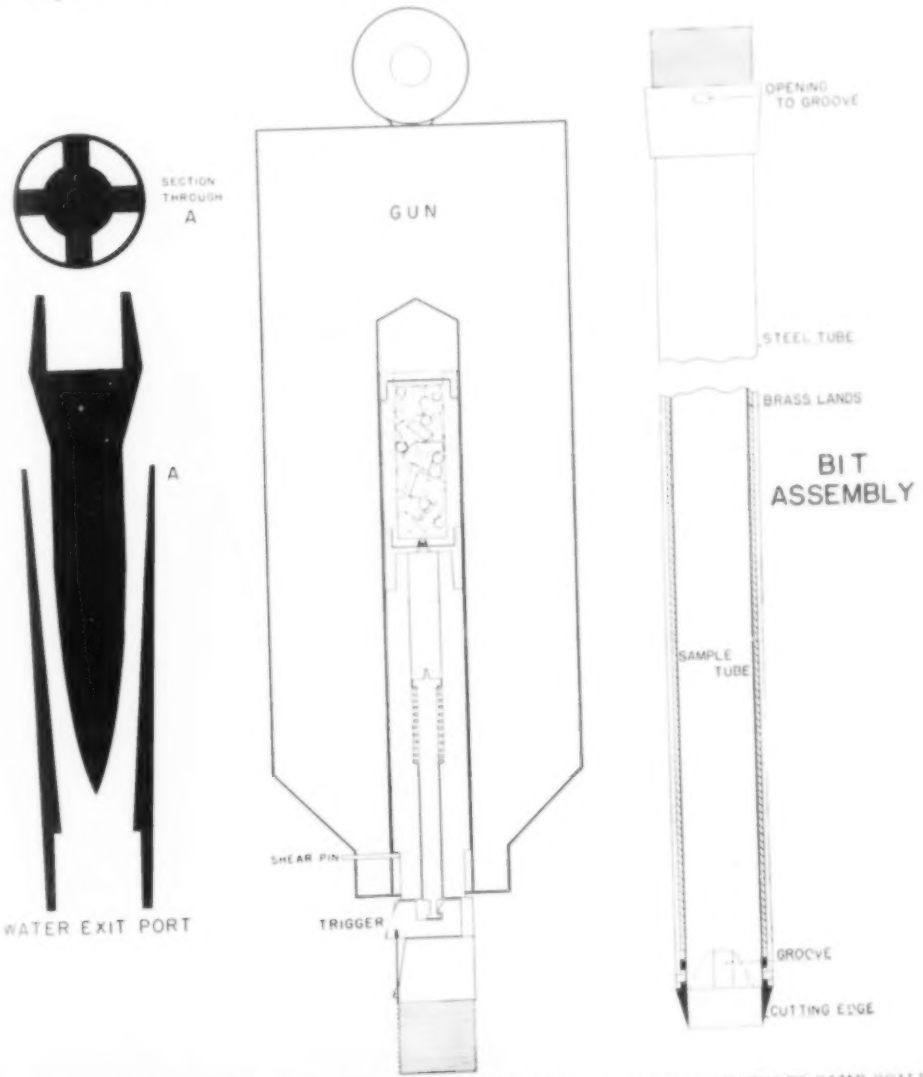


FIG. 2. DIAGRAM SHOWING THE FIVE PRINCIPAL PARTS OF THE APPARATUS, DRAWN TO SAME SCALE.

the depth of water by the simple means of lowering a weight to the bottom has been practised since the beginning of man's adventurings afloat, and quite early there was devised means of knowing something about the *kind* of bottom by the simple expedient of putting a lump of tallow on the bottom of the sounding weight, to which mud, sand or shells, characteristic of the locality, adhered. This device has been used for many hundreds of years and is to-day the chief reliance of the North Sea fishermen.

Attempts at sounding without a line were tried a long time ago, for as far back as 1450 a bathometer was invented which consisted of a floating sphere pulled down by a heavy weight which was disengaged on reaching the bottom. The time elapsing between launching and the reappearance of the sphere at the surface was a measure of the depth. Perhaps the first attempt at scientific deep ocean sounding was that made by Magellan in 1585, during the first circumnavigation of the globe, when he tried to determine the depth of the Pacific Ocean near the island of St. Paul and, because he failed to reach bottom with all his combined lines, concluded that this was the deepest part of the ocean. During his voyage to Baffin's Bay in 1817 Sir John Ross designed a "deep sea clamm" with which he brought up several pounds of greenish mud from depths as great as 1,050 fathoms, which is 6,300 feet, and the presence of worms and starfish established the fact that life existed at great depths.

In 1844 the director of the U. S. Coast and Geodetic Survey instructed its officers to preserve any bottom material brought up by the sounding machine, and this agency has made valuable contributions to the science of oceanography ever since.

By 1850 the need for a better sounding device was urgent, the heavy sounding lines necessary to bring a weight back to the surface were bulky and unwieldy, the deeper the water the stronger the line required, which, with the hemp ropes then used meant more buoyancy, therefore a heavier weight; and the heavy lines gave no indication when the bottom had been reached. As this was the essential part of the undertaking, these incompatible conditions bade fair to defeat the main objective. The difficulty was solved by Midshipman Brooke, of the Hydrographic Office of the U. S. Navy, who passed a short pipe through a hole in a cannon-ball and hung the latter from the former by a sling. This became disengaged when the weight reached the bottom, and only the small pipe with its sample of sediment was brought to the surface. This device permitted the use of a line or wire light enough to show a change in tension when the bottom was reached and yet sufficiently strong to bring up a sample. This scheme of merely pulling down a very light line by means of a weight, which is left on the bottom, is that used to-day in practically all deep-water wire soundings.

Midshipman Brooke's device greatly stimulated deep soundings, and records accumulated rapidly, so that by 1850 Lieutenant Matthew Fontaine Maury, who probably contributed more useful information about the sea than any other investigator, was able to publish the first bathymetric map of the North Atlantic Ocean. The bottom samples secured by these soundings were examined and described by J. W. Bailey, whose publications through the Smithsonian Institution constitute the first scientific information on this subject. In 1851 the U. S. S. *Dolphin* began systematic soundings in the North Atlantic, and in 1852 the U. S. S. *Arctic* ran a line of soundings from Newfoundland to Ireland in an effort to verify the existence of a submarine ridge, on which it was pro-

posed to lay a transatlantic cable. Such a convenient submarine feature does not exist, but the legend of the "telegraph ridge" still persists.

By 1870 more than 9,000 bottom samples had been taken by the U. S. Coast and Geodetic Survey, so that Dr. Louis Agassiz was able to compare dredged forms with fossil types and arrive at the fundamentally important conclusion that since the earliest times the continental areas and the oceanic areas have occupied much the same positions that they do to-day.

All this paved the way for the exhaustive investigations of the physical, chemical and biological conditions of the ocean basins carried out on board H. M. S. *Challenger* from December, 1872, to May, 1876. This expedition circumnavigated the globe, traversed the oceans in many directions, made observations in nearly all the departments of the physical and biological sciences, and laid the foundation for the science of oceanography as it exists to-day. So wide was the field and so extensive the collection assembled that a "Challenger Office" in London is even now occupied with the administration of the varied material. Although the Challenger Expedition is unquestionably the foundation of modern ocean study, it concerned itself more with the water than with the bottom of the ocean, and made no attempt to secure material from below the immediate surface of the latter. This great expedition established the fundamental datum of what *is* happening in the ocean; there is now urgent need of a similarly broad study of what *did* happen in the ocean in the past. This information is in the bottom sediments, and it is to these that we must apply our efforts.

Geological Significance

Now let us turn for a moment to a consideration of some aspects of the structure of the surface of the earth as a whole.

Those of you who heard Dr. Leason Adams speak here last October on the nature and composition of the earth's interior will recall that he used a diagram to illustrate the make-up of the earth's internal structure, whose essential meaning was that the earth has a central core of iron, a thick intermediate layer of heavy, very basic rock and a thin outer cover of less basic material called basalt. On the surface of this basaltic cover are supported here and there irregular patches of lighter rock, mostly granite, but also containing all the other rocks, sedimentary or otherwise, produced in one way or another from the original igneous material. These patches we call the continents. They cover but little more than one fourth of the total surface, while the remaining 72 per cent. is covered by water—which we call the ocean. It is apparent, therefore, that the ocean basins constitute the most conspicuous feature of the earth's surface, and no adequate study of the geologic history of this surface can afford to neglect these great areas.

The floor of the ocean is thought to be the upper surface of the great basaltic cover of the earth, and except where it has been pushed up to form volcanic islands it is, in all probability, essentially as it was when the earth became cool enough to permit water to condense upon its surface. The granitic continental areas on the other hand have undergone many changes; they have risen above the general level, been eroded down, sunk below sea-level at certain places and been heaved up again. Besides these vertical movements there have been horizontal ones—squeezings and stretchings to produce folded mountains and rift-valleys. Joly's doctrine assumes that the ocean floor as well as the continents is periodically heaved up, into a great low arch, that any cracks thereby produced are

filled by upwelling molten material from below and that subsequent sinking of this hardened arch exerts enormous crushing forces at the margins of the continents. The Wegener hypothesis assumes that there was once only one great continent, and that it subsequently broke up into several pieces, which drifted apart under the influence of tangential forces.

Brief mention is made of these geologic conceptions only to emphasize the fact that from the earliest times the interrelations existing between the ocean basins and the continental highlands have been of fundamental importance to the history of the surface of the earth.

Geologists divide this history into different periods, or ages, according to the evidence furnished by uplifted marine sediments, as for instance the Carboniferous, when a moist, warm climate filled vast swamps with rank tropical vegetation; or the more recent Pleistocene, when a cold environment caused great masses of ice to spread over large areas. Each such period deposited its characteristic page in the accumulating record at the ocean bottom. Through these ages the ocean has been receiving the material eroded from the continents, the chemical substances dissolved by the rains and the dust and volcanic ash borne by the wind. As these things changed in character or amount they left their record in the ocean's bottom. The sharp pebbles and coarse sand brought by the ice contrast markedly with the fine flocculent burden of unhurried rivers. This record has been accumulating during many changes on the neighboring continents and during many changes in the water above.

All these records have been laid down in historical sequence, and in some places this sequence has remained undisturbed throughout many geologic ages. Far out from land in the undisturbed depths of the open ocean this record has accumulated very slowly, so that a few feet of depth represent a very long interval of time.

Problems

As illustrative of the sort of investigations which a study of these sediments might be able to assist, let us consider a few typical problems. Certain chemical elements which must have been transported from the rocks of the continents to the waters of the ocean and thence to the sediments in its bottom are of great interest and significance. Some of these occur in large amounts, as, for instance, calcium or chlorine, while others of minute concentrations are none the less significant, as, for example, fluorine or selenium, manganese or radium.

The cycle followed by calcium is quite obvious. This element came originally from igneous rocks, went into the sea, where the myriad organisms built skeletons and shells of it. The organisms died and their shells settled to the bottom, where they were eventually covered and compressed and heated to form chalk, limestone or marble, which was later pushed up into hills to be eroded away and again returned to the ocean.

The story of fluorine is not so clear. This substance is almost as abundant in the original igneous rocks as its chemical companion chlorine. Now chlorine, as sodium chloride, is a dominant constituent of sea-water, but this is not true of fluorine, nor has this element yet been found in appropriate amount in the bottom sediment. It is found in phosphate rock deposits, but although these are large they are hardly sufficient to balance the cycle.

Ores of manganese are relatively rare on land, but quantities of manganese nodules occur on the ocean bottom and in some places there appear to be vast slabs of it covering many square miles. Why this is so we do not know, but in working out the answer we shall probably learn of other facts as yet unsuspected.

The case of the accumulation of radium in the ocean sediments is most in-

triguing, and it was our work with this element that led us into the ocean bottom.

During the last cruise of the non-magnetic ship *Carnegie* a number of samples of bottom were secured from deep water by means of the "telegraph snapper," an instrument used by the submarine cable engineers to give some knowledge of the character of the surface of the bottom. These samples were examined for a great many things, including radium, and, as shown in Table 1, it was found that they possessed a concentration of this element far greater than that existing in the igneous rocks from which it must have come. It will be noticed that the radium concentration is given in grams times ten to the minus twelve per gram. Expressed as a vulgar fraction this is one, over one followed by twelve zeros. This is an exceedingly small amount of radium, but this element possesses to a high degree that phenomenon known as radioactivity whereby the nucleus of the atom periodically explodes and expels from within itself some of its own substance. This explosive activity produces electrical effects by means of which the very small quantities shown may be determined. It also produces a great deal of heat, so much in fact that one gram of radium element, in equilibrium with its disintegration products, continuously gives off 140 gram calories of heat per hour, which is enough to melt more than its weight of ice in that time. It is quite probable, therefore, that radioactivity is a very important factor in geophysical phenomena, and of the several elements that exhibit this activity the most important are radium, thorium and potassium, the first two because of the intensity of their activity, and the last because of its great amount in the rocks. It is the radioactive heat that Joly postulated was able to melt the lower portion of the basaltic layer and, by expanding, to push up the low arch mentioned before. Whether or not it can do such a spectacular thing, it is evident that here is a source of enormous energy which must be seriously considered. Though there is but little radium in each gram of rock there are many grams of rock, and this rock is not a good conductor of heat—and furthermore, geologic time is long—so that it is quite possible that this heat might accumulate sufficiently to account for some of the geophysical phenomena that have been observed.

TABLE 1
COMPARISON OF RADIUM CONTENT OF ROCKS AND OCEAN-BOTTOM SEDIMENTS

		grams × 10^{-12} per gram of sample
Granites		2.0–5.0
Basalts		0.8–1.3
Sedimentary (various ages)		0.1–1.2
Ocean Bottom		
Average of 12 (Joly)		17.8
" " 28 (Pettersson)		10.96
Carnegie Samples		
Type	Depth in meters	
Terrigenous	2604	1.80
"	2911	1.88
"	5396	4.12
"	5545	4.76
"	5198	3.00
Blue Mud	4026	3.08
Globigerina Ooze	4693	3.96
" "	2614	3.88
" "	3393	3.40
" "	3610	4.40
" "	3080	3.64
" "	2898	5.00
" "	3423	5.96
" "	3353	7.84
Red Clay	4007	3.20
" "	3879	3.96
" "	4418	5.80
" "	3806	9.60
" "	5320	6.04
" "	4426	8.96
" "	4713	9.48
" "	5208	10.40
" "	4918	21.40
" "	5003	16.72
" "	4953	10.92
27 Red Clays average		12.1
13 Globigerina Oozes average		4.1

Table 1 shows that the concentration of radium in the uppermost sediments of the ocean bottom is much greater than in either the igneous or sedimentary rocks on land. This high radioactivity is the more astonishing when it is remembered that the sedimentary materials of the continents, even the shales and limestones which were formed under the sea,

contain in general less radium than do the igneous rocks. The geophysical significance of this highly radioactive material depends upon the thickness of the sediments and their history subsequent to being formed. If they are of shallow depth and have not entered into the basaltic crust, their radium content is of little geophysical significance, but if they are of great thickness and have served to take such concentrations of radium into this crust, their influence must be considerable, either as blanketing the flow of heat into the oceans, as is required for Joly's thermal cycles, or as providing sources of intense energy for any part of the crust within which they may become incorporated. The concentration appears to be greatest in those portions of the ocean bottom more remote from land and lying at the greater depths, where the material generally consists of so-called red clay, and it is this material that appears to contain much more radium than any rocks yet examined on land. If these sediments are of considerable thickness, and if this radium concentration is the same throughout, these deeps constitute local concentrations of radioactive material possessing enormous stores of energy. Since we have found no sedimentary rocks with radium concentrations remotely approaching those existing in these deep sediments, it might be inferred that the deeper portions of the ocean, unlike the high mountains, are permanent features of the earth, vast depressions which, since the very beginning of the ocean, have been receiving, together with other things, a large accumulation of radium. Or, on the other hand, this radium concentration may be but a transitory thing, for if this be elemental radium which has separated from the sea-water entirely on its own and is not in equilibrium with its parent substance uranium, it will disappear, almost entirely, in 10 or 20 thousand years, which is only a moment in geologic time. This is because the half life of radium is only 1,600 years, which means that a given amount of radium to-day will diminish to one half this amount in 1,600 years, and this again to one half in another like period, and so on. Consequently, if this radium is "on its own" in the bottom sediment, it must disappear almost entirely below some 20,000 years of accumulation. It has, however, been found one meter below the surface and there is reason to assume that it is not alone, but is being continuously produced by its parent uranium, and that it is due to the chemical behavior of this parent element that a separation from sea-water takes place.

Various mechanisms have been suggested to account for this high concentration of radium in the ocean bottom, some of which seem to have lost sight of the fact that in all probability the significant chemistry involved is the chemistry of uranium and not that of radium per se.

It has been suggested that the concentration is brought about by the numerous minute living organisms in the sea. These are assumed to extract, more or less selectively, the salts of uranium and radium from the sea-water, and to incorporate them in their skeletons, and when they die their remains take the radioactive material to the bottom. If the concentration is brought about by sea organisms we should expect to find some connection between the radium content and the character of animal remains comprising the sediment. Although a few high figures are associated with globigerina or radiolaria deposits, the red clays, which are predominantly minera[1] in composition, show more consistently higher radium contents. If we confine our averages to the more recent analyses we arrive at the figures (see Table 1):

27 red clays average 12.1×10^{-12} grams Ra per gram.

13 globigerina oozes average 4.1×10^{-12} grams Ra per gram.

The uranium must have come originally from the igneous rocks. It exists in the water in solution, and apparently some process is operating to remove it from this solution and to cause it to accumulate in the bottom-sediments at a concentration considerably greater than in the igneous rocks.

The fact that the radium concentration falls off near shore and there approaches more or less the concentration found in sedimentary rocks, which accumulated in shallow seas, indicates that the process is not one of detrital accumulation or sedimentation. Furthermore, the fact that the higher concentration is found in the red clays, which are assumed to accumulate very slowly, and the minerals of which may be partly formed in place, indicates that the skeletal remains of organisms tend to dilute an otherwise higher concentration.

Chemically, uranium, iron and manganese are similar, in so far as their oxides are among their less soluble compounds, and it is usually in those portions of the ocean bottom where the oxides of manganese and iron are separated, as revealed by the nodules of these elements, that the uranium concentration—as revealed by the radium content—is the higher.

If we accept the radium content of seawater as being about 0.02×10^{-12} grams per cc (which is probably high), which corresponds to a uranium concentration of 6×10^{-8} grams per cc, we find that the uranium is not very greatly different from other metallic constituents such as silver, gold or even silicon, from which so many marine organisms build their skeletons (Table 2). In all probability there are several factors aiding in its separation and concentration in those places where it is found to be most abundant. Skeletal remains may take down some, also dust particles of volcanic or other origin may adsorb some and sweep it to the bottom; but probably the greater proportion comes out as the result of oxidation. Water which is near enough to continents, or shallow enough to have sufficient organic material at the bottom to maintain a slightly reducing environment, tends to keep its uranium in solution, whereas the very deep bottom waters, far from land, do not contain organic material either washed from the land or as undestroyed organisms; consequently they afford an oxidizing environment. That these waters are oxidizing is borne out by the direct measurements of the oxygen content with depth made by the *Carnegie*, a typical graph of which is shown in Fig. 3. This shows that the environment at the bottom of the ocean is of an oxidizing rather than reducing nature. In the deeper parts of the ocean where there is little movement, the water at the bottom must be at saturation with respect to the oxides of uranium. There is, therefore, a tendency for them to separate out just as the iron and manganese do.

TABLE 2

URANIUM AND SOME OTHER METALLIC CONSTITUENTS OF SEA-WATER

Uranium	6.0×10^{-8}	grams	per	cc
Silicon	46.9×10^{-8}	"	"	"
Silver	10.0×10^{-8}	"	"	"
Gold	0.06×10^{-8}	"	"	"

APPARATUS

Nearly all the ocean-bottom samples hitherto obtained have consisted of a small amount of material taken from the immediate surface. They yielded no knowledge of what lay below—no perspective of sequence or time. To cope with the types of problems just discussed it is necessary that an undisturbed cross-section of the bottom sediments be obtained, the deeper the penetration the better, but it is essential that the sample reach the laboratory in exactly the condition existing in the bottom of the ocean.

These requirements have been met by an apparatus which has been developed by virtue of the generous cooperation of

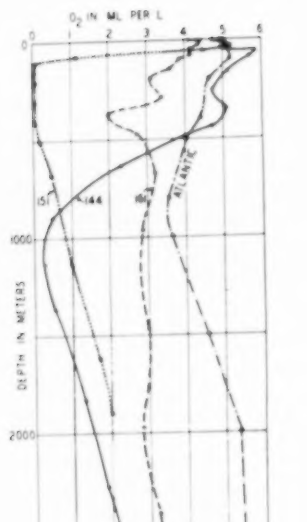


FIG. 3. OXYGEN CONCENTRATION IN THE SEA AT VARIOUS DEPTHS.

many persons, particularly that of Dr. B. F. Mackey, ballistics expert of the E. I. du Pont Powder Company, and the U. S. Lighthouse Service, from whose tenders many tests were conducted. This apparatus has obtained undistorted cores as much as ten feet long, from bottoms lying more than three miles below the surface of the water, and we believe it will function satisfactorily even at the bottom of the greatest deep, which is 5,900 fathoms, or more than six and one-half miles down. There the hydrostatic pressure is 16,000 pounds per square inch.

Now the requirements for an apparatus designed to operate at the end of a line under several miles of water, and at great hydrostatic pressures, are varied and somewhat conflicting. One can not lower a weight faster than the winch can run the line out, and furthermore, skin friction is such that a considerable weight sinks slowly with several miles of line behind it and arrives at the bottom with almost no kinetic energy. Consequently in deep soundings one can not rely on the energy of a falling weight to do any considerable work at the bottom. Nor is it feasible to send the necessary energy down a sounding line, as, for instance, in the form of electricity. No wire rope made can support the weight of six miles of itself and retain any reasonable factor of safety, and an insulated electric conductor would diminish this strength considerably.

Even if insulation and mechanical difficulties were overcome, such a rope could not long survive the constant bending over sheaves and drum at high tension, and any motor designed to operate machinery under several miles of corrosive sea-water would be so bulky and heavy, to say nothing of cost, as to be out of consideration. A heavy weight is an asset on the way down, but a liability on the way up, and sufficient strength must be reserved to pull the sample out of the mud once it is secured. Furthermore, the pitching and rolling of the ship on the waves at the surface impose strains on the rope far greater than those of dead weight or the pull-out. The fact that no one rope is strong enough in proportion to its weight necessitates the construction of a tapered rope, which becomes bigger and stronger as the weight increases. Such a rope greatly complicates the spooling, or winding on the winch drum, for unless this is done smoothly and compactly, the enormous pressures of superimposed layers under tension will cause cross-lapped ropes to crush and cut each other.

Any satisfactory apparatus should be

as light as possible, of simple design and operation and of rugged construction. It should be capable of attachment to any existing sounding line strong enough to hold it, and it must function entirely automatically on reaching the bottom. For this reason, it must possess within itself the energy necessary to accomplish the work to be done.

Of all the sources of energy considered, that possessed by modern military powder seemed most likely to succeed. It is highly concentrated, presents no special problems of manipulation, and may be varied in intensity and amount to suit the changes of hydrostatic pressure or the resistance of the bottom material.

The apparatus, in its present state of development, consists of five parts: a weight, or gun, a cartridge, a firing mechanism, a water exit port and a bit. These parts are shown in Fig. 2 drawn to the same scale. The gun is made of ordinary cold rolled steel 10 inches in diameter and 22 inches long. The cartridges, trigger and housing are of stainless steel. The water port is of welded steel, and the bit of a special alloy steel developed for airplane construction. Only the cartridges must withstand the great hydrostatic pressures, and since they are designed for high internal pressures, this presents no particular difficulty. They consist of three parts—a midsection or powder chamber and top and bottom sections. In the bottom of the powder chamber is a recess into which a rifle primer fits. Over this is placed a thin steel disk, against which the bottom section screws tightly, in the center of which is a small hole, opposite the primer, through which the point of the firing-pin may strike the disk with sufficient force to distort it and thereby fire the primer.

Inside the muzzle end of the powder chamber rests a hardened steel disk, one-eighth inch thick, with its outer surface flush with the end of the powder chamber. Its function is to take the strain of the hydrostatic pressure of the sea-water and thereby prevent distortion of the rupture disk. The rupture disk is of steel and of such thickness and strength that it will allow the pressure within the cartridge to build up to the proper working pressure before it ruptures and releases the energy to the mechanism.

Powder Charge

The explosive charge which furnishes the energy necessary to do the required work varies with the depth and the character of the bottom. The charge consists of a primer, 1 gram of high-speed black powder, 1 gram of rifle powder and a varying number of pellets of 155-mm howitzer powder. The 2 grams of small powder play the double role of promoting ignition and quickly building up a pressure, in which environment the large-grained powder functions explosively. If this high pressure were not provided, the latter would not burn properly.

The total available energy is regulated by counting into the cartridge a varying number of pellets of the big powder. This required energy is of three parts: (1) That which is necessary to overcome the hydrostatic pressure at a particular depth; (2) that which is necessary to overcome the inertia of the bit and to put it in motion; and (3) that required to drive the bit into the particular material encountered. Only the second can be determined in advance; the other two must be provided for at each sounding. The possible work that can be done is a combination of the total available energy and an intensity factor, *i.e.*, the pressure at which the explosive gases are released. This "working pressure" is controlled by the steel rupture disk at the mouth of the cartridge. Up to the time this disk is blown out, the powder is protected from the water. These disks are relatively thin and, therefore, capable of distortion, and at a certain depth the hydrostatic pressure might conceivably be greater

than the desired "working pressure"—hence the use of the steel "hydrostatic pressure disk," which relieves the rupture disk of all strain. By virtue of this arrangement, and the use of the large-grained powder, there is obtained a more or less automatic adjustment of the delivered power to the required work. For example, if 30 pellets of big powder are put into a cartridge and it is sent to 1,000 fathoms and encounters a stiff clay, the added pressure and resistance will cause the powder to burn more rapidly, and all of it will be converted into gas; whereas, if the same charge encountered a very soft bottom at a shallow depth, only that powder would be consumed which had burned up to the time the muzzle was cleared—which would occur sooner than in the former case. The optimum load, therefore, is one which leaves a grain or two of partly burned powder in the cartridge. The ultimate condition is that which exists when the bit lands on solid rock and all the energy must go into moving the gun, which is then blown upward and thereby saves the apparatus from destruction. The bits have been made strong enough to meet this extreme condition.

The firing mechanism consists of only three parts, a trigger, firing-pin and spring. A safety-pin of hardened steel is put in place before the cartridge is attached, and this is withdrawn by means of a lanyard just before the apparatus goes under the water. Should it be necessary to return the apparatus to the deck, before firing, this pin can be inserted again before the apparatus is hoisted over the side.

Because of the high velocity of the bit at the time of firing, the water within it acts as a solid body. During early experiments the bit was often driven deep into the mud, but no samples were obtained. The water exit port gives the bit an open-tube condition at the top while keeping the force of the explosion centered along the axis of the bit. The length of the bit determines the possible length of the sample. Bits of different lengths may be used as found desirable. Those now being used are 10 feet long. Inside the steel tube are four grooves cut longitudinally from top to bottom. Their function is to provide channels by which water may get down to the bottom of the bit and to fill the cavity in the mud created by the withdrawal of the bit and its

FIG. 4. APPARATUS READY TO SOUND, SAFETY-PIN BEING PULLED BY LANYARD.

sample. A thin-walled brass sample-tube fits inside the steel bit, and it is this tube that receives the sample. The bottom of the bit is fitted with a hardened cutting edge which fits loosely, in such a manner as to act as a valve to prevent mud from entering the water grooves while the bit is being driven into the bottom, but which opens and permits water to flow out of the grooves while the bit is being withdrawn from the mud.

FIG. 5. BIT RETURNED TO SURFACE, HANGING FROM STIRRUP. GUN IS ABOVE, OUT OF THE PICTURE.

After a "shot," the brass sample tube is withdrawn, with the mud core inside it, and a new one is inserted. It is cut off at the top of the mud, corked at both ends, and these corks securely taped. They are labeled in a manner to indicate the top and the bottom of the core and may then be shipped and kept without alteration until opened for examination in the laboratory. This is done by cutting the tube longitudinally in two diametrically opposite places and then inserting two sheets of tin in one slot and pressing them across to the opposite wall. The tube may then be opened hinge-fashion and the tin strips removed without distorting the sample. This produces two equal parts to each sample, each part lying in its own brass trough, and reveals the structure of the core. This procedure provides an undisturbed half for control or future reference and the other may be used for investigation. Furthermore, the undisturbed half provides a depth scale, from the surface downward, which is of considerable value. It has been found convenient to split the half to be examined, either in half again or into quarters. The fragments may always be returned to their proper place in the brass trough.

SOUNDING PROCEDURE

The apparatus is assembled in chocks, so arranged that when it is laid in them the center of the bit and cartridge coincides with the center of the bore of the gun. The firing mechanism is cocked and the safety-pin inserted. A cartridge is loaded in accord with the anticipated need. If it is the first sounding in a new locality, it is advisable to provide rather less than the required energy. Subsequent loads may be increased as circumstances warrant. When all is ready, the cartridge is fastened in place and the gun "loaded," by sliding the bit toward the gun, and the shear pin is put in place. The apparatus is then hoisted over the

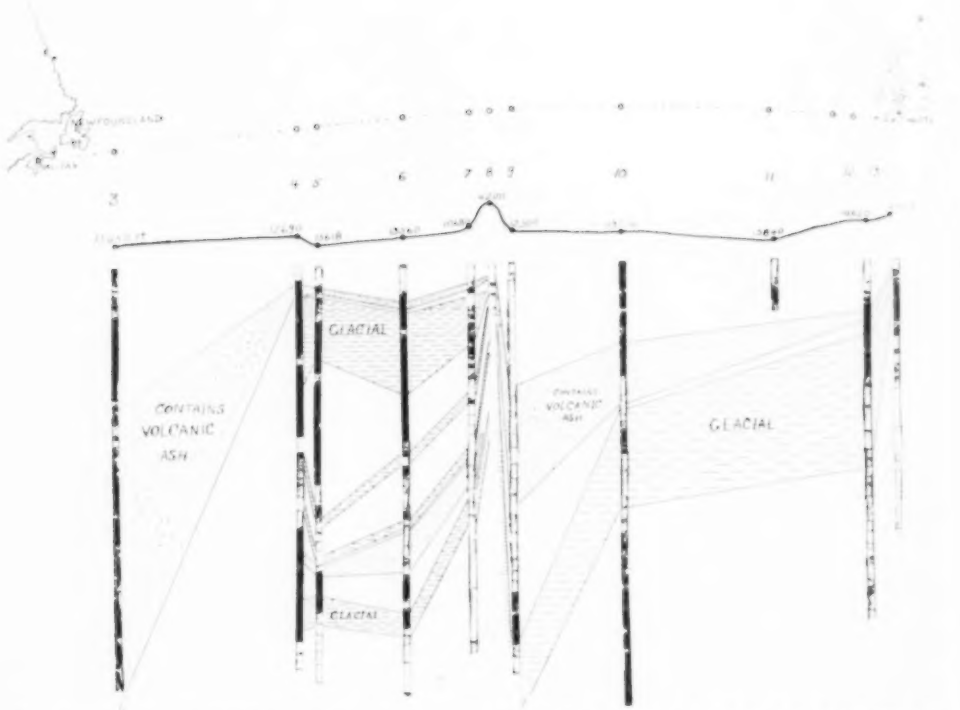


FIG. 6. NORTH ATLANTIC CORES, SHOWING DEPTH AND LOCATION OF EACH AND THE RELATION OF THE GLACIAL AND VOLCANIC-ASH STRATA.

side. A man picks up the bit at the cutting edge and, as soon as the gun clears the rail, he drops his end over the side into the water. The apparatus is immediately lowered until only the gun is out of water; this prevents swinging against the ship's side (Fig. 4). Finally, the safety-pin is pulled out and the apparatus is lowered to the bottom. With shallow soundings the explosion can be heard and felt on the ship, and with deeper ones it may also be picked up by a microphone or the ship's sonic sounder. Where these fail to give any indication, the cable is paid out until more than the anticipated depth is out, and then the apparatus is hauled to the surface again. If it has fired, the gun and bit will be hanging separately at the end of their respective cables, the bit supported in the stirrup (Fig. 5).

With the cooperation of the Woods Hole Oceanographic Institution, sixteen soundings were made at sea in August, 1935, yielding the 14 cores shown in Fig. 7. One failure was due to a defective primer, and once the core pulled out. The 14 cores vary in length from 4 feet to nearly 9 feet and are solid throughout. The depths of these soundings varied from 200 fathoms to 1,250 fathoms.

The 11 cores shown in Fig. 9 were obtained from the Western Union Cable Ship *Lord Kelvin* during May, 1936, between the Grand Banks of Newfoundland and the edge of the continental shelf southwest of Ireland.[1] Seven of them

[1] The success of this undertaking is due to the courtesy of Mr. Newman Carlton, chairman of the board of directors of the Western Union Telegraph Company, and of Vice-President F. E. d'Humy and Mr. G. H. Ridge, and especially to the enthusiastic cooperation of Lieutenant Commander Bredin Delap (R. N., retired), then in command of the ship, and acting 1st officer W. Adamson. Thanks are particularly extended to Chief Engineer Tierney and his staff, who made many emergency repairs. From every

FIG. 7. CORES TAKEN FROM SUBMARINE CANYONS AUGUST 1935, AT DEPTHS OF 1,200–7,500 FEET. 6-FOOT RULE FOR COMPARISON.

are from depths greater than 2,000 fathoms, and all the remainder but one from more than 1,000 fathoms. The one exception is from the top of the Faraday Hills at 700 fathoms. The greatest depth was 2,650 fathoms. The very short core contains several inches of weathered rock.

Fig. 8 shows these cores split open ready for study, arranged, as taken, from west to east across the North Atlantic. The cracks are due to drying. This can be prevented by keeping the cores in a saturated atmosphere, but since the dried segments leave marks on the brass troughs which establish their positions from the surface, this is not usually done.

In February, 1937, again with the co-operation of the Woods Hole Oceanographic Institution, cores were obtained from the Bartlett Deep, between Jamaica and Cuba, at a depth of 2,800 fathoms or 16,800 feet (more than three miles).

The North Atlantic cores are being studied by a group of cooperating specialists associated with Dr. W. H. Bradley, of the U. S. Geological Survey. This group also includes Messrs. M. N. Bramlette, J. A. Cushman, L. G. Henbest, K. E. Lohman and P. D. Trask. The final results of their studies are not yet available, but enough has been completed to show that within the reach of the ten-foot bit are records of four glacial periods, and two periods characterized by the presence of fragments of volcanic ash. These are illustrated in Fig. 6. Core No. 3 is entirely "blue mud" or recent sediment. This is probably due to the presence of the Labrador Current, which has

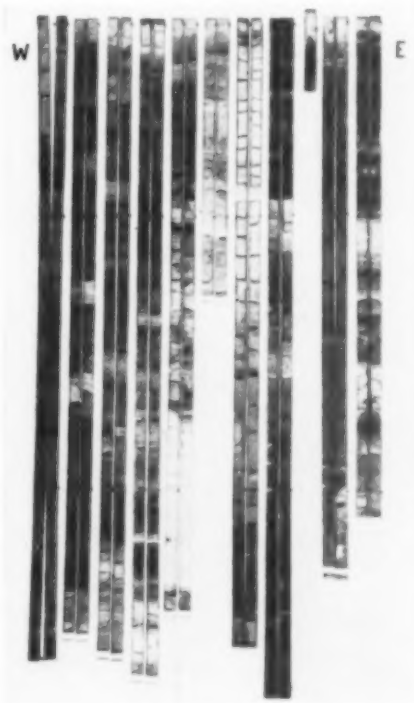


FIG. 8. SAME CORES AS FIG. 6 SPLIT LONGITUDINALLY AND ARRANGED AS TAKEN FROM WEST TO EAST.

officer and man on the ship there was always a friendly spirit of interested cooperation and courtesy which made the undertaking a delightful experience as well as a success.

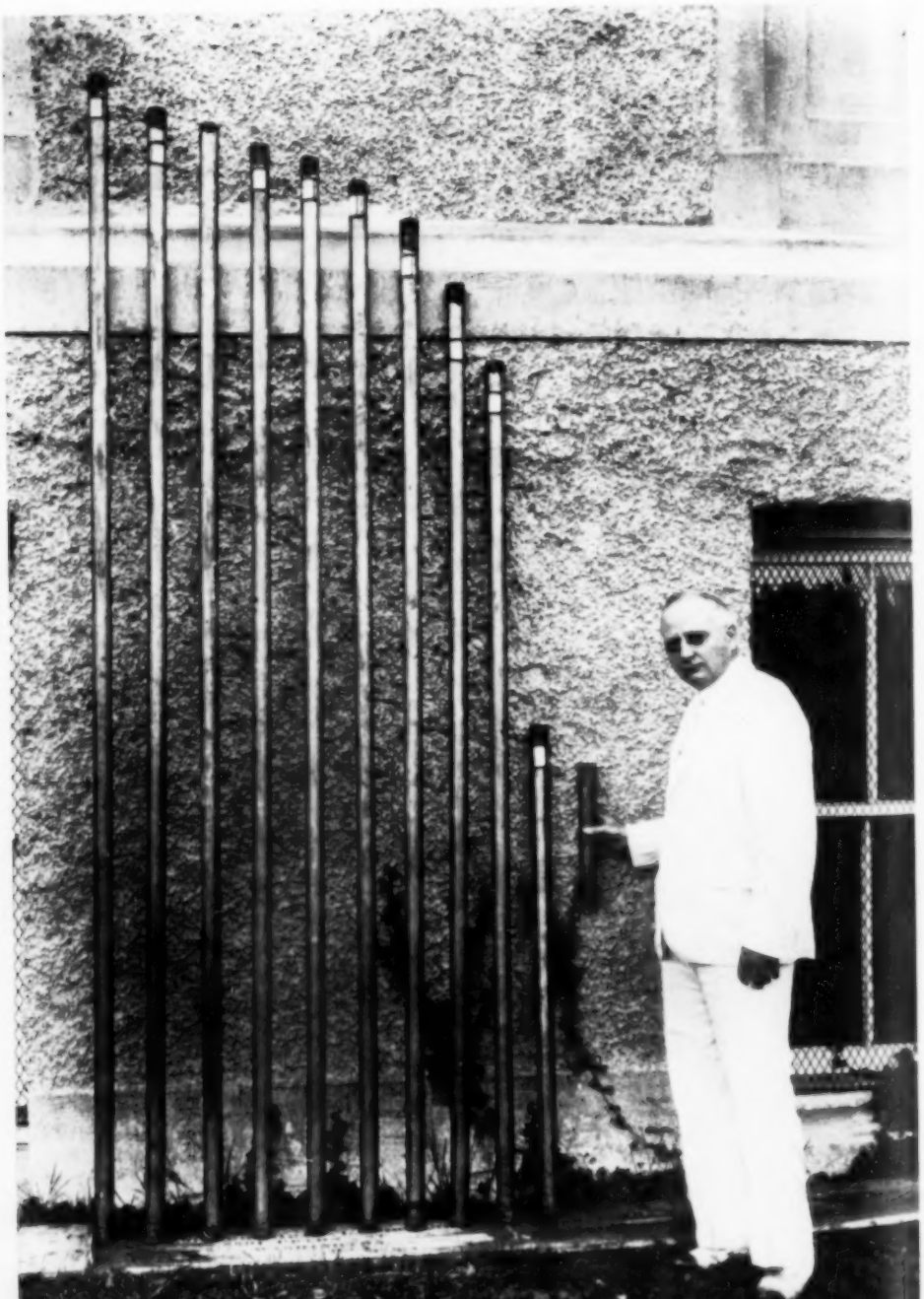


FIG. 9. CORES FROM THE NORTH ATLANTIC BETWEEN NEWFOUNDLAND AND IRELAND, 1936. DEPTHS 4200–15,900 FEET. LONGEST IS 10 FEET, SHORTEST CONTAINS SOME ROCK.

brought additional material to that region during the time represented by the upper portion of the other cores. From Core No. 4 to Core No. 8 the six characteristic strata can be traced. Core No. 8 was taken from the top of the Faraday Hills, as the Mid-Atlantic Ridge is called at that place. The general set of the water in that part of the North Atlantic is toward the east and northeast, and apparently this tends to sweep material off the top of this high, narrow ridge and deposit it in the valley beyond. Therefore the cores taken between the Ridge and the continental shelf off Ireland did not penetrate through to the three other glacial zones which undoubtedly lie buried there. The chemical, mineralogical and biological information yielded by these samples is equally definite. The biological agreement is particularly striking. Dr. Cushman made his studies of the foraminifera quite independently of the geological group. He prepared a diagram indicating cold and warm water periods as revealed by the remains of these minute creatures. When this diagram was superimposed upon the stratigrapher's map it fitted with astonishing coincidence. Between the glacial periods and below the lowest glacial zone the forms indicate that the water was as warm or warmer than it is to-day.

Dr. Byers, of the U. S. Department of Agriculture, is finding in these cores the lost selenium, which is found in the soil and in river waters but not in sea-water.

An unexpected and rather spectacular investigation is being undertaken by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, which is finding these cores helpful in a study of the changes in the orientation of the earth's magnetic field. Consider a minute particle of a magnetic mineral (and there are many such) settling slowly through the quiet water at the bottom of the ocean. Like a tiny compass needle it orients itself along the line of the magnetic force at that place and at that time. A multitude of such particles become buried in the sediment, and their orientation in these cores can be determined by delicate electrical apparatus. Therefore, as this orientation shifts back and forth throughout the length of the core, it reveals the cyclic changes of the lines of magnetic force throughout the past. Here is a record such as the nonmagnetic ship *Carnegie* might have compiled had it been cruising the seas for several hundred thousand years or so.

Conclusion

The two greatest features of the earth's surface are the continental elevations and the oceanic basins. The drainage from the former into the latter has been a continuing process since the beginning of geologic history. This drainage has been the mechanism whereby this historical record has been compiled. Although the portion of this record corresponding to remote ages can not be reached, a considerable period of more recent geologic time can be studied. The first requirement is a study of a "normal" drainage —one not affected by agriculture or industry—and one which is continental in its scope. The two greatest drainage systems of the world, namely, the Amazon and the Congo, meet these requirements. They both drain large continental areas and deposit their burden in the South Atlantic. Both are practically unaffected by agriculture or industry. A physical, chemical and biological study of the sediments from well within such a river's mouth, out across the submerged delta, across the zone of increasing effect of salt water and into the deep ocean-basin beyond, would teach us much of the processes reflecting the relationships now existing between these great continental areas and the receptive sea. Knowledge of such normal, present relations would enable us to recognize abnormal conditions elsewhere (as of the Mississippi, the Ganges or the Yangtze) and to interpret the evidence contained in the record of the more distant past.

THE TRANSMUTATION OF MATTER

By the late LORD RUTHERFORD OF NELSON[1]

The Transmutation of Matter

I have so far spoken of the importance of science as a factor in national development, but before concluding my address, I would like to refer to some investigations in pure science in which I have been personally much interested. I refer to the successful attack on that age-old problem of the transmutation of matter which in recent years has attracted so much attention from physicists throughout the world.

I hope it may prove of interest to give a brief account of the successive stages of the growth of our knowledge of this subject, for it illustrates in a striking manner the power of the scientific method of attack on what at first appeared to be an insoluble problem. Incidentally these researches have yielded us precious information on the structure of all atoms, and indeed it seems likely to have provided us with a key, so to speak, to unlock the secrets of the constitution of our material world.

Towards the close of the nineteenth century, when it seemed certain that the atoms of the elements were unchangeable by the forces then at our command, a discovery was made which has revolutionized our conception of the nature and relations of the elements. I refer to the discovery in 1896 of the radioactivity of the two heaviest elements, uranium and thorium. It was soon made clear that this radioactivity is a sign that the atoms of these elements are undergoing spontaneous transmutation. At any moment, a small fraction of the atoms concerned become unstable and break up with explosive violence, hurling out either a charged atom of helium, known as an α particle, or a swift electron of light mass, called a β particle. As a result of these explosions, a new radioactive element is formed and the process of transmutation once started continues through a number of stages. Each of the radioactive elements, formed in this way, breaks up according to a simple universal law, but at very different rates. In a surprisingly short time, these successive transformations were disentangled and more than 30 new types of elements brought to light while the simple chemical relations between them were soon made clear.

We had thus been given a vision of a new and startling sub-atomic world where atoms break up spontaneously with an enormous release of energy quite uninfluenced by the most powerful agencies at our disposal. Apart from uranium and thorium and the elements derived from them, only a few other elements showed even a feeble trace of radioactivity. The great majority of our ordinary elements appeared to be permanently stable under ordinary conditions on our earth. Science was then faced with the problem whether artificial methods could be found to transmute the atoms of the ordinary elements. Before this problem could be attacked with any hope of success, it was necessary to know more of the actual constitution of atoms. This information was provided by the rise of the nuclear theory of atomic structure which I first suggested in 1911. The essential controlling feature of all atoms was found to reside in a very minute central

[1] Concluding part of the presidential address before the Indian Science Congress Association, prepared by Lord Rutherford before his death and presented to the congress meeting in Calcutta on January 3. This is the last part of the address, which contains two other sections—one on "Science and Industry in India" and one on "Industrial Research in Great Britain."

nucleus which carried a positive charge and contained most of the mass of the atom. A relation of unexpected simplicity was found to connect the atoms of all the elements. The ordinary properties of an atom are defined by a whole number which represents the number of units of resultant positive charge carried by the nucleus. This varies from 1 for hydrogen to 92 for the heaviest element uranium, and with few exceptions all the intervening numbers correspond to known elements.

On this view of atomic structure, it was evident that, to bring about the transmutation of an atom, it was necessary in some way to alter the charge or mass of the nucleus or both together. Since the nucleus of an atom must be held together by very powerful forces of some kind, this could only be effected by bringing a concentrated source of energy of some kind to bear on the individual nucleus. The most energetic projectile available at that time was the swift α particle spontaneously ejected from radioactive substances. If a large number of α particles were fired at random at a sheet of matter, it was to be expected that one of them must occasionally approach very closely to the nucleus of any light atom in its path. In such a close encounter, the nucleus must be violently disturbed and possibly under favorable conditions the α particle might actually enter the nuclear structure.

This mode of attack upon the nucleus at once proved successful. I found in 1919 that nitrogen could be transformed by bombardment with fast α particles. The process of transmutation is now clear. Occasionally an α particle actually enters the nitrogen nucleus and forms with it a new unstable nucleus which instantly breaks up with the emission of a fast proton (hydrogen nucleus) and the formation of a stable isotope of oxygen of mass 17. About a dozen of the light elements were found to be transformed in a similar way. The protons liberated in the nuclear explosions were at first counted by observing the flashes of light (scintillations) produced in phosphorescent zinc sulfide. This method was slow and very trying to the eyes of the observers. Progress, however, became more rapid and definite when electrical methods of counting individual fast particles were developed. These electrical counters, mainly depending on the use of electron-tubes for magnifying small currents, have now reached such a stage of perfection that we are able to count automatically individual fast particles like α particles and protons, even though they enter the detecting chamber at a rate as fast as ten thousand per minute. By other special devices, we are in like manner able to count individual β particles. In this connection, I must not omit to mention that wonderful instrument, the Wilson expansion chamber, which makes visible to us the actual tracks of flying fragments of atoms resulting from an atomic explosion. These remarkable devices have played an indispensable part in the rapid growth of knowledge during the last few years. It is to be emphasized that progress in scientific discovery is greatly influenced by the development of new technical methods and of new devices for measurement. With the growing complexity of science, the development of special techniques is of ever-increasing importance for the advance of knowledge.

Up to the year 1932, experiments on transmutation were confined to the use of α particles for bombarding purposes. It became clear that the process of transformation was in most cases complex, since groups of protons with different but characteristic energies were observed when a single element was bombarded. This led to the conception that discrete energy levels existed within a nucleus and that under some conditions part of

the excess energy was sometimes released in the form of a quantum of high frequency radiation.

The stage was now set for a great advance, and four new discoveries of outstanding importance were made in rapid succession in the period 1931–3. I refer to the discovery of the positive electron by Anderson in 1931, of the neutron by Chadwick in 1932, of artificial radioactivity by M. and Mme. Curie-Joliot in 1933 and of the transmutation of the elements by purely artificial methods first shown by Cockcroft and Walton in 1932.

The discovery of the neutron—that unchanged particle of mass nearly 1—was the result of a close study of the effects produced in the light element beryllium when bombarded by α particles. It is noteworthy that the proton and neutron, which are now believed to be the essential units with which all atomic nuclei are built up, owe their recognition to a study of the transmutation of matter by α particles.

Before the discovery of the neutron, it had been perforce assumed that nuclei must in some way be built up of massive protons and light negative electrons. Theories of nuclear structure became much more amenable to calculation when the nucleus is considered to be an aggregate of particles like the proton and neutron which have nearly the same mass. There was no longer any need to assume that either the positive or the negative electron has an independent existence in the nuclear structure. We are still uncertain of the exact relation, if any, between the neutron and the proton. The neutron appears to be slightly more massive than the proton, but it is generally believed, although no definite proof is available, that the proton and neutron within a nucleus are mutually convertible under certain conditions. For example, the change of a proton into a neutron within the nucleus should lead to the appearance of a free positive electron, while conversely the change of a neutron into a proton gives rise to a free negative electron. In this way it appears possible to account for the observed fact that either positive or negative electrons are emitted by a large group of radioactive elements to which I will now refer.

In the early experiments on transmutation by α particles, it was supposed that a stable nucleus was always formed after the emission of a fast proton. The investigations of M. and Mme. Curie-Joliot showed that in some cases elements were formed which, while momentarily stable, ultimately broke up slowly, exactly like the natural radioactive bodies. Most of these radioactive bodies formed by artificial methods break up with the expulsion of fast negative electrons, but in a few cases positive electrons are emitted. Since the presence of these radioactive bodies can be easily detected, and their chemical properties readily determined, this new method of attack on the problem of transmutation has proved of great value. Nearly a hundred of these radioactive bodies are now known, produced in a great variety of ways. Some arise from the bombardment by fast α particles, others by bombardment with protons or deuterons. As Fermi and his colleagues have shown, neutrons and particularly slow neutrons are extraordinarily effective in the formation of such radioactive bodies. On account of its absence of charge, the neutron enters freely into the nuclear structure of even the heaviest element and in many cases causes its transmutation. For example, a number of these radioactive bodies are produced when the two heaviest elements uranium and thorium are bombarded by slow neutrons. In the case of uranium, as Hahn and Meitner have shown, the radioactive bodies so formed break up in a succession of stages like the natural radioactive bodies, and give rise to

number of trans-uranic elements of higher atomic number than uranium (92). These radioactive elements have the chemical properties to be expected from the higher homologues of rhenium, osmium and iridium of atomic numbers 93, 94 and 95.

These artificial radioactive bodies in general represent unstable varieties of the isotopes of known elements which have a limited life. No doubt such transient radioactive elements are still produced by transmutation in the furnace of our sun where the thermal motions of the atoms must be very great. These radioactive elements would rapidly disappear as soon as the earth cooled down after separation from the sun. On this view, uranium and thorium are to be regarded as practically the sole survivors in our earth of a large group of radioactive elements, owing to the fact that their time of transformation is long compared with the age of our planet.

It is of interest to note what an important part the α particle, which is itself a product of transformation of the natural radioactive bodies, has played in the growth of our knowledge of artificial transmutation. It is to be remembered, too, that our main source of neutrons for experimental purposes is provided by the bombardment of beryllium with α particles. The amount of radium available in our laboratories is, however, limited, and it was early recognized that if our knowledge of transmutation was to be extended, it was necessary to have a copious supply of fast particles of all kinds for bombarding purposes. It is well known that enormous numbers of protons and deuterons, for example, can be easily produced by the passage of the electric discharge through hydrogen and deuterium (heavy hydrogen). To be effective for transmutation purposes, however, these charged particles must be given a high speed by accelerating them in a strong electric field. This has involved the use of apparatus on an engineering scale to provide voltages as high as one million volts or more and the use of fast pumps to maintain a good vacuum.

A large amount of difficult technical work has been necessary to produce such high D.C. voltages and to find the best methods of applying them to the accelerating system. In Cambridge these high voltages are produced by multiplying the voltage of a transformer by a system of condensers and rectifiers; in the United States by the use of a novel type of electrostatic generator, first developed by van der Graaf. Professor Lawrence, of the University of California, has devised an ingenious instrument called a "cyclotron" in which the charged particles are automatically accelerated in multiple stages. This involves the use of huge electromagnets and very powerful electric oscillators. By this method, he has succeeded in producing streams of fast particles which have energies as high as the α particle ejected from radioactive substances. Undoubtedly this type of apparatus will prove of great importance in giving us a supply of much faster particles than we can hope to produce by the more direct methods.

It was at first thought that very high potentials of the order of several million volts would be required to obtain particles to study the transmutation of elements. Here, however, the development of the theory of wave-mechanics came to the aid of the experimenter, for Gamow showed that there was a small chance that comparatively slow bombarding particles might enter a nucleus. This theoretical conclusion has been completely verified by experiment. In the case of a light element like lithium, transformation effects can be readily observed with protons of energy as low as 20,000 volts. Of course, the amount of transformation increases rapidly with rise of voltage.

The study of the transmutation of elements by using accelerated protons and deuterons as bombarding particles has given us a wealth of new information. The capture of the proton or deuteron by a nucleus leads in many cases to types of transmutation of unusual interest. For example, the bombardment of the isotope of lithium of mass 7 by protons leads to the formation of a beryllium nucleus of mass 8 with a great excess of energy. This immediately breaks up with two α particles shot out in nearly opposite directions. When boron 11 is bombarded by protons, a carbon nucleus of mass 12 is formed which breaks up in most cases into three α particles. The deuteron is in some respects even more effective than the proton as a transmuting agent. When deuterons are used to bombard a compound of deuterium, previously unknown isotopes of hydrogen and of helium of mass 3 are formed, while fast protons and neutrons are liberated. The bombardment of beryllium by very fast deuterons gives rise to a plentiful supply of neutrons. Lawrence has shown that the bombardment of bismuth by very fast deuterons leads to the production of a radioactive bismuth isotope, which is identical with the well-known natural radioactive product radium E. Many artificial radioactive elements can be produced often in great intensity. For example, the bombardment of common salt by fast deuterons gives rise to a radioactive isotope of sodium. This breaks up with a half period of 15 hours, emitting not only fast β particles but γ rays at least as penetrating as those from radium.

It may well be that in course of time such artificial radioactive elements may prove a useful substitute for radium in therapeutic work. By these methods also, such intense sources of neutrons can be produced that special precautions have to be taken for the safety of the operators of the apparatus.

Sufficient I think has been said to illustrate the variety and interest of the transmutations produced by these bombardment methods. It should, however, be pointed out that transmutation in some cases can be effected by transferring energy to a nucleus by means of gamma rays of high quantum energy instead of by a material particle. For example, the deuteron can be broken up into its components, the proton and neutron, by the action of the gamma rays from radium or thorium. As a result of the bombardment of lithium by protons, gamma rays of extraordinarily great quantum energy as high as 17 million volts are strongly emitted. Bothe has recently shown that these high energy rays are able to transmute a number of atoms, neutrons usually being emitted in the process.

Some simple laws appear to hold in all individual transformations so far examined. Nuclear charge is always conserved, and where heavy particles are emitted, so also is energy when account is taken of the equivalence of mass and energy. Certain difficulties arise with regard to the conservation of energy in cases where light positive and negative electrons are emitted during transmutation, and there is still much discussion on this important question.

The study of the transmutation of matter has been extraordinarily fruitful in results of fundamental importance. In addition to the α particle, it has disclosed to us the existence of those two building units of nuclei, the proton and neutron. It has greatly widened our conception of the varieties of atomic nuclei which can exist in nature. Not only has it led to the discovery of about one hundred new radioactive elements, but also of several stable isotopes of known elements like ^{2}H, ^{3}He, ^{8}Be which had previously been unsuspected. It has greatly extended our

knowledge of the ways in which nuclei can be built up and broken down, and has brought to our attention the extraordinary violence of some of the nuclear explosions which occur. The great majority of our elements have been transmuted by the bombardment method and in the case of the light elements which have been most carefully studied a great variety of modes of transmutation have been established.

Rapid progress has been made, but much still remains to be done before we can hope to understand the detailed structure and stability of different forms of atomic nuclei and the origin of the elements. I can not but reflect on the amazing contrast between my first experiment on the transmutation of nitrogen in the University of Manchester in 1919 and the large-scale experiments on transmutation which are now in progress in many parts of the world. In the one case, imagine an observer in a dark room with very simple apparatus painfully counting with a microscope a few faint scintillations originating from the bombardment of nitrogen by a source of α particles. Contrast this with the large-scale apparatus now in use for experiments on transmutation in Cambridge. A great hall contains massive and elaborate machinery, rising tier on tier, to give a steady potential of about two million volts. Nearby is the tall accelerating column with a power station on top, protected by great corona shields—reminding one of a photograph in the film of Wells's "The shape of things to come." The intense stream of accelerated particles falls on the target in the room below with thick walls to protect the workers from stray radiation. Here is a band of investigators using complicated electrical devices for counting automatically the multitude of fast particles arising from the transformation of the target element or photographing with an expansion chamber, automatically controlled, the actual tracks of particles from exploding atoms.

To examine the effect of still faster particles, a cyclotron is installed in another large room. The large electromagnet and accessories are surrounded with great water tanks containing boron in solution to protect the workers from the effect of neutrons released in the apparatus. A power station nearby is needed to provide current to excite the electromagnet and the powerful electric oscillators.

Such a comparison illustrates the remarkable changes in the scale of research that have taken place in certain branches of pure science within the last twenty years. Such a development is inevitable, for, as science progresses, important problems arise which can only be solved by the use of large powers and complicated apparatus, requiring the attention of a team of research workers. If rapid progress is to be made, such team work is likely to be a feature of the more elaborate researches in the future. Fortunately, there is still plenty of scope for the individual research worker in many experiments of a simpler kind.

The science of physics now covers such a vast field that it is impossible for any laboratory to provide up-to-date facilities for research in more than a few of its branches. There is a growing tendency in our research laboratories to-day to specialize in those particular branches of physics in which they are most interested or specially equipped. Such a division of the field of research amongst a number of universities has certain advantages, provided that this subdivision is not carried too far. In general, the universities should be left free as far as possible to develop their own lines of research and encouraged to train young investigators, for it can not be doubted that vigorous schools of research in pure science are

vital to any nation if it wishes to develop effectively the application of science, whether to agriculture, industry or medicine. Since investigations in modern science are sometimes costly, and often require the use of expensive apparatus and large-scale collaboration, it is obviously essential that adequate funds should be available to the universities to cover the cost of such researches.

In this brief survey I have tried to outline the contributions to scientific knowledge made in India, and the needs of the immediate future if science is to play its part in the national welfare. While the study of modern science in India is comparatively recent and naturally much influenced by Western ideas, it is well to recall that India in ancient days was the home of a flourishing indigenous science, which in some respects was in advance of the rest of the world at that time. The study of ancient writings has discovered in recent years the extent and variety of these scientific contributions, which notably advanced the study of arithmetic and geometry. The researches of Sir Prafulla Ray have also brought to light the important advances made in metallurgy and chemistry. May we not hope that this natural aptitude for experimental and abstract science, shown so long ago, is still characteristic of the Indian peoples, and that in the days to come India will again become the home of science, not only as a form of intellectual activity but also as a means of furthering the progress of her peoples.

THE SKEPTICAL PHYSICIST

By Dr. PAUL R. HEYL
NATIONAL BUREAU OF STANDARDS

THOSE of you who are acquainted with the history of science will recognize the source whence I have plagiarized the title of this article. In the middle of the seventeenth century the young science of chemistry was in a state which troubled the conscience of the Honorable Robert Boyle, whose interest in this science was life-long. There was a theory widely held at that time that all substances were composed of three primary principles—salt, sulfur and mercury. In "The Sceptical Chymist," published in 1661, Boyle combatted this idea, criticizing the experiments upon which it was based and pointing out among other things the difference between mixtures and compounds. Modern chemistry owes much to the pioneer work of Boyle, and his merits were not unappreciated by his contemporaries, who dubbed him "the father of chemistry and the brother of the Earl of Cork."

The term "skeptical" has an etymology from which its present-day meaning has widely departed. The Greeks applied the adjective σκεπτικός to a person who gave thoughtful consideration to matters which called for action or decision. The antithesis of such a skeptic was the person who acted on impulse or emotion. Perhaps because the judgment of the skeptic was so often adverse, he gradually became recognized as a chronic doubter or even as an iconoclast. It is possible, however, that these adverse opinions may have been due in many cases not to original sin in the skeptic, but to essential unsoundness in the subjects that he was called on to consider.

I like to think that Boyle used the term "skeptical" in its original sense, and in that sense I may be permitted to use it in the present discussion. It is as true now as when Victor Cousin said it, nearly a century ago, that "la critique est la vie de la science," and the history of science shows that situations arise at frequent intervals where the application of this principle is called for. When criticism is stifled, science is dead.

One of these situations confronts us at the present time and has called forth a protest from a skeptical physicist to which scientific men of all households of faith may well give attention, for though it is the science of physics that is immediately concerned, the situation involves the fundamental question of the attitude of the scientific man toward nature.

I refer to Dr. Herbert Dingle and his article on "Modern Aristotelianism," which appears in *Nature* for May 8, 1937. The replies, pro and con, to this article were so numerous and extensive that it was necessary to devote an entire supplement of *Nature* to them (June 12, 1937). It will, I think, be interesting and profitable to give a résumé of Dingle's article and of some of the replies to it.

Dingle's article may appear to have been inspired by published statements by Eddington and Milne, but between the lines there are some of us who can read sympathetically the story of a slowly growing skepticism which has finally burst all bounds.

The term "Aristotelianism," as Dingle uses it, does not refer so much to the doings and thinkings of Aristotle himself as to the habit of mind and the outlook upon nature of the medieval scholars who acknowledged the great Stagirite as their master. Orthodox science since Galileo's day has held that the first step in the study of nature is the observation of phenomena, from which we may pass by

induction to the derivation of general principles. The "Aristotelianism" to which Dingle refers, and which dominated the scholastic thought of the western world up to the seventeenth century, was the doctrine that there are general principles known *a priori* to the human mind apart from observation or sense perception.

For instance, Aristotle reasoned that a heavy body must fall more rapidly than a lighter one, and this *a priori* principle was accepted and believed by the Aristotelians for 2,000 years, until it was shown by experiment and observation that such was not the fact. As Emerson says, "Things are in the saddle, and ride mankind."

For three centuries this Aristotelian view of nature has been regarded, at least by scientific men, as dead. It is, therefore, as Dingle says, no light matter when we find in our own day a revival of Aristotelianism in the front ranks of science itself. As ground for this serious charge Dingle quotes statements by Eddington and by Milne.

Eddington[1] says: "There is nothing in the whole system of laws of physics that can not be deduced unambiguously from epistemological considerations. An intelligence unacquainted with our universe but acquainted with the system of thought by which the human mind interprets to itself the content of its sensory experience, should be able to attain all the knowledge of physics that we have attained by experiment."

Milne[2] is somewhat more restrained and conservative when he says, "It is, in fact, possible to derive the laws of dynamics rationally . . . without recourse to experience."

Statements like these, coming from leaders in science, are indeed serious, and it will be interesting to see what their authors have to say in their own defense.

[1] "Relativity Theory of Protons and Electrons," p. 327.

[2] *Proc. Roy. Soc.*, A, 158, 329; 1937.

Eddington stands by his guns, remarking that the passage cited by Dingle has been likewise quoted "without its safeguards" by almost all the reviewers of his book. And what are these safeguards? Eddington makes it clear that the quoted passage must not be interpreted as the *a priori* basis of his philosophy, but is the unexpected conclusion at which he has arrived as the result of his investigations.

And what are these investigations?

Some years ago Eddington, by an abstruse mathematical discussion which he states did not involve any observational measurements, arrived at a figure for the mass-ratio of the proton and electron which was quite close to the accepted experimental results. Still later he calculated by a relativistic-wave-mechanics method that the total number of elementary particles in the universe is $2 \times 136 \times 2^{256}$. This result still awaits experimental check.

"After a rather extensive series of researches," says Eddington in his reply to Dingle, "I have found that a great part of the current scheme of physics is deducible by *a priori* argument." But he goes on to admit that "since we can have no *a priori* knowledge of an objective universe such results do not constitute knowledge of an objective universe." Just what they do constitute he does not make clear.

Milne, in his defense, takes much the same position as Eddington. Dingle's criticism of Milne was directed in part against his doctrine of "kinematical relativity," which is a study of the consequences of the assumption that the universe is, on the average, homogenous both in distribution and motion. In developing the consequences of this assumption Milne endeavored to avoid any empirical appeal and to develop the physics of the universe after the manner of a logical geometry based upon axioms or space-definitions. In carrying out this development Milne appears to have made the

same discovery as Eddington. Milne remarks that it is an astonishing thing to find that the elimination of empirical appeal, including all appeals to quantitative laws of physics, can be carried as far as it can; and that with the elimination of such empirical appeals regularities emerge which play the part of the very laws of nature which are observed to hold good.

Milne admits that his resulting logical structure may not correspond to nature any more than do the various hypergeometries that have been invented, but says that just as results of value have followed from the development of such non-realizable abstractions as a four-dimensional cube, so it may be valuable to construct an abstract physics for its own sake.

This is a reasonable defense. As long as the limits of such investigations are clearly recognized, and they are held strictly within these limits, they may be as valuable and stimulating as any other scientific speculations. But the essence of Dingle's criticism is that this line of action can be carried to such excess and be given such a color as to deceive the very elect. When those to whom we look for scientific leadership can say, in effect, "Don't experiment; calculate! It is easier, cheaper, more exciting and productive of results," then science is on its way back to the Aristotelianism of the Middle Ages.

The ability of a theory to calculate and predict phenomena is an asset of undoubted importance, but it is not enough, and must not be over-rated. A modern instance of this is Bohr's theory of atomic structure. The flexibility and accuracy with which the Bohr atom adjusted itself to the manifold conditions required by the periodic law of the elements were remarkable. The Bohr theory moved along with regular steps, dropping the right element into each empty compartment provided by the periodic law. When it came to the rare earths the theory halted for a moment, dropped exactly the right number of elements all into the same compartment, and then resumed its measured tread, dropping one element at each step until all were put in their proper places. No wonder that Whetham characterized this behavior as "satanic." Yet with all this to its credit the Bohr atom, because of its failure to meet three requirements, had to give place to a still more adaptable theory as soon as one could be found.

The theory of relativity is in a similar position to-day. It has done much; it has explained one astronomical puzzle for which the Newtonian law of gravitation was inadequate; it has predicted two other physical phenomena whose existence has been experimentally verified; but when it comes to such a simple matter as centrifugal force, then, as Eddington himself says, the theory stops explaining phenomena and begins explaining them away. The theory of relativity holds its own to-day only because no one has as yet been able to devise a better.

The failure of a theory for reasons of this character need reflect no discredit upon its author. We can still admire a theory which has marked a step in progress, which has been able to cut a little more closely to the line than any which preceded it, even though it be soon superseded by a better. But some theoretical researches in modern physics fall into a different category, and tend to make the skeptical physicist a little more skeptical.

These researches are for most of us difficult reading. Perhaps this is unavoidable, considering the nature of the subject. We of the rank and file must frequently take the results of our leaders on faith; and unfortunately we sometimes find in those portions which we can understand that which seriously shakes our confidence in the parts that we can not follow. When, for example, Edding-

ton[3] says that the mass of the sun is 1.47 kilometers, and repeats this in the second edition of his book, and when Minkowski[4] points with pride to what he calls "the mystic formula," 3×10^5 km $= \sqrt{-1}$ sec, and when it requires no knowledge of the calculus of tensors to see what the trouble is, the only conclusion possible is that the fundamental principles of mathematics and physics are like the laws of whist—for beginners to observe and for masters to disregard.

Minkowski's memoir on "Space and Time," in which this "mystic formula" occurs, has long enjoyed the reputation of a classic. It antedates Einstein's general theory of relativity by seven years, and in his paper of 1915 Einstein acknowledges his debt to Minkowski. Minkowski's memoir contains the concepts of the four-dimensional space-time continuum, of world lines and of space-like and time-like vectors, upon which basis has been erected a vast structure of relativistic cosmology. With this "mystic formula" staring us in the face it will be interesting to examine the philosophical basis of Minkowski's theory.

The fundamental idea of the memoir is that time in some way bears a fourth-dimensional relation to our solid space. Now, of course, time has not the dimensions of a length, but if we multiply it by a velocity that defect disappears. Minkowski multiplies the time t by the velocity of light c, thus obtaining the length ct, which may be used as a fourth dimension. Unfortunately, it happens that an important equation resulting from this hypothesis is not symmetrical.

Now every mathematician has in him something of the artist; an eye for symmetry, for beauty of results and for elegance in the methods used in obtaining them. Now an unsymmetrical equation offends the artistic sense; in addition, it is scientifically undesirable, as results can not be obtained from it as readily as from a symmetrical form. And here Minkowski had a brilliant idea. If we multiply the fourth dimension ct by $\sqrt{-1}$ the unsymmetrical equation becomes symmetrical.

Of course this gives us a set of four axes, three of which are real and one imaginary, but any difficulty attaching to this detail is soon forgotten in the dazzling light of the brilliant results that begin to appear. For example, referred to our new coordinates, the complicated Lorentz transformation appears as a mere rotation of the axes—which, however, involves the turning of the imaginary axis through an imaginary angle.[5] Whether this makes the Lorentz transformation any more comprehensible is a question—which the artist-mathematician answers in the affirmative.

$\sqrt{-1}$ has a legitimate application in pure mathematics, where it forms a part of various ingenious devices for handling otherwise intractable situations. It has also a limited value in mathematical physics, as in the theory of fluid motion, but here also only as an essential cog in a mathematical device. In these legitimate cases, having done its work it retires gracefully from the scene; but to make an imaginary quantity a permanent foundation stone for a physical hypothesis is, as they say in Ireland, a white horse of another color.

There is no denying the potency of $\sqrt{-1}$ as a useful tool. As an illustration, I may point out how it helps us to an

[3] "Report on the Relativity Theory of Gravitation," second edition, 1920, p. 50.

[4] "Raum und Zeit," an address before the German Convention of Natural Scientists and Physicians, Cologne, September 21, 1908. *Phys. Zeitschrift*, Vol. X, p. 104, 1909. English translation in "The Principle of Relativity; memoirs by Lorentz, Einstein, Minkowski and Weyl," New York, Dodd, Mead and Co., 1923.

[5] Minkowski discusses this point very briefly. The complete mathematical treatment is given by Eddington in his "Report on the Relativity Theory of Gravitation," second edition, 1920, page 14.

interesting little theory of gravitation. Einstein, in discussing the resemblance between inertia and gravitation, considers the case of a revolving circular platform. Suppose such a disk large enough to hold an observer, and let it be covered by a dome so that the observer within can not tell by direct observation of outside bodies whether the disk is in motion. Let the disk be at rest. The observer, in moving from one place to another in his little world, would notice no difference between one point and any other. Let the disk be now set in rotation. The observer, unless he stood at the center of the disk, would experience a force urging him radially outward, and the farther he was from the center the greater would be this force. He would, in fact, be living in a sort of turned-inside-out gravitational field.

As a theory of gravitation there are two defects in this. The force increases with the distance from the center; and it is in the wrong direction, outward instead of inward. The first of these defects is quite easy to remedy. We may suppose the speed of rotation of the disk to be variable, governed either by a mechanical device or by a watchful engineer so that the speed will increase as the observer approaches the center, and will diminish as he nears the circumference.

The other defect is not so easy to dispose of. It is obviously useless to give the disk a negative velocity of rotation, as the centrifugal force depends on the square of the velocity. But if we multiply the velocity not by -1 but by $\sqrt{-1}$, the trick is done.

Everybody laughs at this; nobody laughs at Minkowski. Yet I have done nothing but what Minkowski has done. I have turned my disk through an imaginary angle; Minkowski turned his axes of coordinates through an imaginary angle. The trouble is that I have made my illustration so simple that any one can see through it. Had I made it as abstruse as Minkowski's memoir it might have been received with equal seriousness. Truly, as Dingle says, the criterion for distinguishing sense from nonsense has been lost; our minds are ready to tolerate anything, if it comes from a man of repute and is accompanied by an array of symbols in Clarendon type.

And yet we must not be too hard on $\sqrt{-1}$; it may stand us in good stead on occasion, as is instanced by a tradition of the National Bureau of Standards.

In the early days of the Bureau, when the staff was smaller, and there were no official guides, the staff-members took turns in conducting parties of visitors through the laboratories. On one such occasion the visitors were shown some liquid air, and they asked, "What is this used for?" In those days liquid air had not yet found any practical application, and was merely a scientific curiosity. The guide, who tradition says was one of the lady-members of the staff, was rather non-plussed for the moment, but quickly recovered her presence of mind, and replied, "It is used to lubricate the square root of minus one."

I sometimes think Minkowski must have heard that story.

NEED FOR RESEARCH ON GRASSLANDS[1]

By HERBERT C. HANSON and C. T. VORHIES

NORTH DAKOTA AGRICULTURAL COLLEGE AND UNIVERSITY OF ARIZONA

OCEANS, forests and deserts stir the minds of men. The vastness and power of the ocean, the grandeur and hidden depths of the forests and the extreme conditions of the desert appeal to the imagination. Yet to the uninitiated grassland is monotonous in its seeming uniformity over wide vistas: the distant horizons are unbroken, the "plains" are endless. In past times settlers hesitated before leaving the forest behind to enter the grasslands or "barrens" where fuel and building materials were lacking and the elements, especially wind and sun, held full sway. Man is not originally an animal of the plains but rather a creature of the forests or, at least, of the margins of the forests. Knowledge of the grassland, acquired often only through deeply felt or painful experience, leads to appreciation of the widespread, the uninterrupted view and the fertile soil, or perhaps to despair at recurring droughts and persistent, drying, hot or freezing winds.

Oceans, forests and deserts deserve all the attention they receive. On the other hand, grasslands have been strangely slighted; they demand greater attention from the points of view not only of practical economics but also of evolutionary and ecological thought. Grasslands conceal vast unexplored stores of scientific facts which, when brought to light, will enrich the fields of plant and animal ecology, evolution, climatology, geography and geology. The knowledge to be gained from them may contribute significantly to the solution of problems concerning the evolution of grassland plants and animals; the influences of diverse environments, from tropical lowlands to deserts and alpine summits, upon distribution and origin of species; the results of interrelations between plants and animals under widely varying environments; the linkage of present geographic distributions and characteristics of grassland species to forest, aquatic and desert species and to earlier geological species and conditions. Study of the teeming life along the seacoasts began with the Greeks and is continued to-day in numerous marine laboratories with results of unquestioned significance to biological science and human welfare. Investigations in the generally neglected grasslands may be fully as fruitful in contributions to the needs of our civilization. The analysis and correlation of great stores of data secured from seas and lakes, from forests and deserts, and from the grasslands are essential to the formulation of sound concepts and principles in numerous fields of learning. Especially is there need for this study of grassland faunas. We now use these lands for grazing domestic animals in enormous numbers, although we have never made the requisite basic studies of the relations of native grassland faunas to grasses. In actual fact we have so over-utilized the grasslands that now, when we are compelled to face the necessity of fundamental research, we find ourselves with practically no such lands in original condition for investigations.

[1] Prepared for the Committee on Ecology of Grasslands of North America of the National Research Council. The writers are indebted for numerous suggestions to Dr. V. E. Shelford, chairman of this committee, and Dr. R. E. Coker, chairman of the Division of Biology and Agriculture, National Research Council, Washington, D. C.

The significance of grasslands becomes much more apparent when we learn of their vast extent and diverse aspects. About three fourths of the earth's surface is covered with water. Of the remaining one fourth, some 52 million square miles, about 42 per cent. is classified as grassland, about 33 per cent. as forest and 25 per cent. as desert. The grasslands, then, have a total extent far exceeding that of either forest or desert and approaching half of the total land area. In the United States about 38 per cent. of the total land area of 1,903 million acres was originally grassland. Sixteen per cent. of the total land area was tall grass, or prairie; 14 per cent. short grass or plains; and 8 per cent. other types of grassland, as marsh, alpine meadow and desert grassland. Of these great areas almost nothing remains as it was, either floristically or faunistically, to teach us lessons of basic importance in the perpetuation of a most valuable resource. That the grasslands have been largely mismanaged as to the grasses is now widely known; that they have been mismanaged as to their animal inhabitants is just beginning to be realized.

J. W. Bews presented a few years ago a theory of ecological evolution of grasslands based upon facts derived from geographic distribution, from fossil botany, from the taxonomic characteristics of tribes, genera and species of grasses and from the environmental characteristics of habitats of grasses. Bews emphasized that the theory is incomplete for lack of sufficient data. The theory is nevertheless a valuable one because it integrates facts from various fields to give a natural classification of grasslands. The most primitive grasses, such as the Bamboos, are associated with tropical forests and forest margins. The woodland grasses of temperate regions are slightly more advanced. More highly developed are the grasses found in the chaparral type of woodland such as is found in the vicinity of Berkeley, Calif. The grasses of marsh and stream-bank are closely related both floristically and ecologically to those of forest margins, and the aquatic grasses probably originated from the former. Grasses characteristic of saline soil are connected with aquatics and with sand-loving grasses. The latter are connected with nearly all the classes mentioned, since it is but a short step from grasses with trailing stems which root at the nodes, as found in forest edges, to the sand binders with subterranean traveling stems.

According to Bews, fossil evidence supports the view that the primitive grasses were species with high moisture requirement, such as those found in tropical forest margins. The larger tropical and subtropical bunch-grasses, found in extensive savannas, probably developed from tropical forest margins through the intermediate stage of tropical high grass savannas. Higher in tropical mountains alpine grasses developed from bunch-grasses. The extensive temperate grasslands, prairies and plains were formed by grasses that originated from species of temperate woodland and stream-bank. The arid species of semi-deserts and deserts are closely connected with sand and salt grasses and these are among the most highly developed of all species of grass. We see then that, geologically speaking, the large grass areas of the world are recent creations.

In all probability the evolution of major species of animals was contemporaneous with the evolution of grasslands. In the well-known evolution of the horse there are found all stages of change from a small forest animal to the magnificent beast of the plains, which finally became one of man's most important domestic animals in the Old World. In the meantime it mysteriously disappeared from the Western Hemisphere, although its reintroduction has proven its continued adaptation to the grasslands which, fol-

lowing the Spanish conquest, it quickly overspread.

No less significant and interesting were the development of the camel, bison, antelope, coyote, buffalo wolf, jackrabbit and many lesser species. Now most of these have nearly disappeared before man, the arch-destroyer, while others, such as the jack rabbit and some smaller rodents, have enormously increased, doubtless in some cases as a direct result of man's ill-judged activities.

The rounding out of this story of the evolution of grasslands requires the collection and analysis of facts from many study centers in prairies and plains, marshes, meadows and savannas, and alpine, arctic and tropical regions. In these centers detailed studies and analyses of the plant and animal populations and of their relations to one another and to the environment should be continued over a long period of years and supplemented by precise studies of geographic distribution and paleontological data. Grassland investigations of a quantitative nature, continued over many years in one location, are absolutely essential to furnish the fundamental facts upon which to build theories of evolution, such as that of Bews, and biological concepts and principles in general.

Land planning must remain inadequate, short-sighted and wasteful of biological and soil resources until there is much more complete knowledge of grasslands and their fauna than we now possess. In spite of this great need for dependable facts and principles there is now no provision in the United States for studying grasslands in a thoroughly basic manner over a long period of years. This kind of study requires setting aside for a long period of time tracts of adequate size for the sole purpose of acquiring thorough knowledge of grasslands; it requires, in addition, suitable support for a competent staff of investigators.

Grasslands are widely distributed in North America. They extend from the aspen park lands of Alberta, Saskatchewan and Manitoba through the prairie and plains states into southern Mexico, from Ohio to Washington, Oregon and California. The prairie lands are broken in the east by deciduous forest and in the west by coniferous forest and desert. Marshes border the seacoasts and lakes, and sand grasslands are dotted over the country. Several classifications have been made of these wide-spread grasslands, but all of them are based upon fragmentary data. A natural classification can not be completed until much additional information has been secured from intensive, long-continued investigations. The tall-grass grassland or prairie, extending eastward from the 97th and 98th meridians and originally occupying seven-eighths of Iowa, for example, is unique in being the largest area in the world of this type of fairly moist grasslands. Leading dominants are the bluestems, needle-grass, dropseeds, panic grasses and wild rye. West of the prairie and extending to the eastern limits of the Rocky Mountains occur the mixed prairie and plains, or short-grass grasslands, comparable to the steppes of Russia. Restriction of moisture mainly to the surface two feet, droughts and high winds are inimical to tree growth, but the dominant grama grasses, buffalo grass, wheat grasses and low sedges are adapted to these rigorous conditions. The desert grasslands, extending from southwestern Texas through southern New Mexico into Arizona and Mexico, dominated by several species of grama grass, three-awn grass and mesquite grass, is adapted to even more severe aridity. Extensive areas in valleys and foothills in California and Lower California, formerly dominated by bunch grasses such as needlegrasses, June grass and wild ryes, have been replaced, following overgrazing and fire, by annual weeds such as wild oats, ripgut, foxtail chess and wild barleys. The productiveness of the Pa-

Photo by Herbert C. Hanson

BORDERLINE AND TENSION OR COMPETITION ZONE BETWEEN TWO GRASS COMMUNITIES

A PUCCINELLIA-DISTICHLIS COMMUNITY ON THE LEFT MEETS A SPARTINA-PANICUM COMMUNITY ON THE RIGHT. KILLDEER, NORTH DAKOTA. COMPETITION AND MIGRATION STUDIES ARE NEEDED.

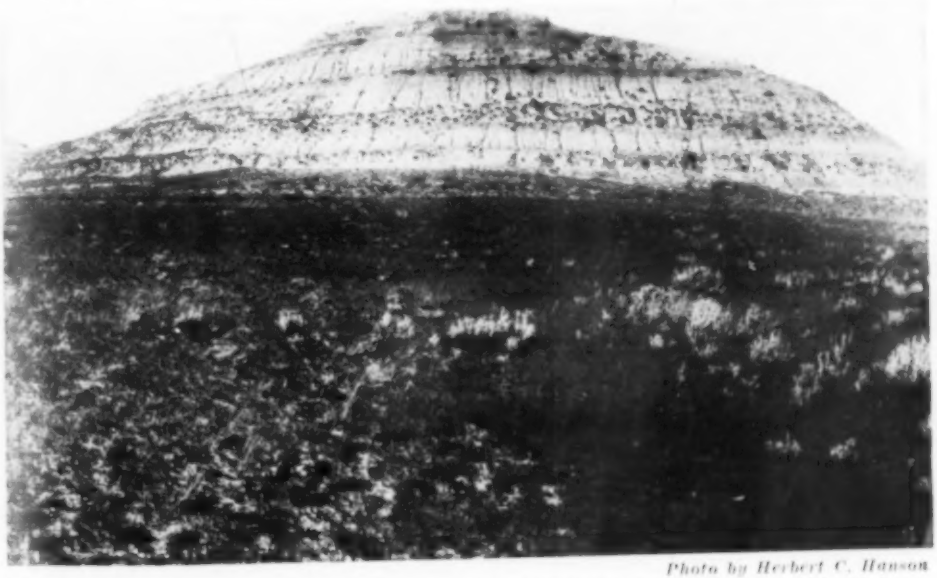


Photo by Herbert C. Hanson

THE DEVELOPMENT OF A STABLE COMMUNITY FOLLOWING EROSION OF A SMALL BUTTE

LARGE AREAS ARE NEEDED FOR STUDIES OF SUCH PROCESSES.

Photo by Herbert C. Hanson

SUCCESSION OR THE DEVELOPMENT OF A PLANT–ANIMAL COMMUNITY

NATURAL IMPROVEMENT OF LAND ON THE PLAINS IN NORTHEAST COLORADO THROUGH THE INVASION OF A BARE AREA BY MATS OF ARENARIA HOOKERI IS SHOWN. HOW MUCH TIME IS REQUIRED TO PRODUCE GRASSLAND? IT INVOLVES MIGRATION OF PLANTS FROM DISTANCE AND THE QUESTION OF THE INFLUENCE OF ANIMALS ARISES. LONG-TIME STUDIES ON LARGE AREAS UNDER PROTECTION ARE NEEDED TO ANSWER SUCH QUESTIONS.

louse wheat lands is due largely to the bunchgrasses, including bluebunch wheat-grass and sheep fescue, the dominants in the Palouse prairie which formerly occupied an extensive area in eastern Washington and Oregon, northern Utah and southern Idaho.

Little effort has been made to use grasslands in their original condition. Aided by the "Westward Ho" movement, by the lack of a constructive land policy, by the expansion in power farm machinery and the demand during the world war for more wheat, there has been a scramble, at times a frenzy, to "break" the sod. This drive to settle the West and plow up the grassland did not stop until millions of acres were turned "wrong side up" and the dust clouds, blown from these lands, reached the Atlantic seaboard. Now, after a large part of our grasslands have been wasted, interest is being shown in this natural resource and we begin to appreciate its value. The immediate and insistent demand is to get the land back into grass; but to restore is no easy matter. Nature required thousands of years to produce these grasslands which, as they existed before breaking up and consequent erosion, were the result of countless interactions of plants, animals and climatic and soil conditions. The best that can be done now is to try to adjust human operations to nature's processes and requirements. Reseeding will aid in the hastening of invasion; but much more is necessary. In man's struggle with the environment there are two alternatives; he must either change unfavorable factors so that they will be more favorable to his well-being or he must adjust himself to these factors. This law operates in man's relations with grasslands, which in many places have now gotten out of control in consequence of mismanagement. Man made a serious mistake when he attempted to make all grassland more favorable to his well-being

by plowing, draining, burning, overgrazing, etc. He has learned that to avoid greater evils much land must be restored to grasses. He may have learned also that he must adjust himself to the needs and ways of grasslands and grassland animals if he is to survive in grassland country.

There's the rub. How can man adjust himself to something that he knows so little about? Fundamental scientific research has been very limited. Most of the investigations have been prompted by practical questions which demanded early answers, such as: What is the grazing capacity of this area? What class of live stock is this range suited to? How can the density of desirable forage plants be increased? How can undesirable species, poisonous plants and destructive animals be eliminated? Elimination of certain animals has been atempted empirically without the requisite basis of knowledge, although it now begins to appear that in many instances proper management of the areas would suffice for the control of species that are objectionable only in excessive numbers. Usually only spasmodic and short-lived study has been given to such fundamental topics as these: the origin of grasslands; the quantitative composition of the flora and fauna and its variability in relation to season; the influence of climatic and soil conditions upon botanical composition; the interrelations of plants and animals; the rate of soil building by various types of grasslands; the interrelations of such ecological processes as competition, reaction and succession. Dr. J. E. Weaver, of the University of Nebraska, has carried on research in these subjects in the vicinity of Lincoln, Nebraska, since 1915, and he was preceded by Dr. F. E. Clements and Dr. Charles Bessey, who laid foundations in the nineties. This is the only place in the United States where long-continued fundamental studies have been conducted consistently. In consequence, the prairies of eastern Nebraska are understood better perhaps than any other natural grasslands in the world. It is most regrettable, however, that these studies have been dependent upon such year-to-year arrangements as could be made with the owners of the study areas. There has been the continuous threat that the owners would plow up the prairie instead of mowing it for hay. Many desirable experiments could not be conducted because the investigator did not have complete control of the areas under study. The U. S. Forest Service has studied grasslands in various parts of the West for many years, especially in southern New Mexico, southern Arizona and in the mountains of Utah. The Forest Service studies have primarily the practical purpose of developing grazing methods that will maintain maximum yields of forage, produce live stock most effectively, and be in harmony with other forest uses such as the protection of watersheds. The investigations of a federal government agency such as the Forest Service, as well as those of many state experiment stations, must, in order to secure annual appropriations, provide answers to the immediately practical problems pressed upon them by their constituents. Unless the rancher receives information or help on how to decrease death losses due to suspected poisonous plants, what to seed on an abandoned field or, in short, how to produce more efficiently and to market more effectively, he is likely to take advantage of the opportunity to decrease his taxes a mite by withdrawing his support for these experimental agencies. Under such conditions it is extremely difficult to conduct a research program on a broad and fundamental basis which requires long and certain tenure of suitable land, adequate equipment and personnel and freedom from the pulling and pushing of political factions and the pressures of narrow-minded groups that have special axes to grind.

The desert studies and other investiga-

Photo by Herbert C. Hanson

POCKET GOPHER MOUNDS FURNISHING BARE AREAS FOR INVASION OF WESTERN WHEATGRASS

THE HETEROGENEITY OF PRAIRIE VEGETATION IS INCREASED. MUCH MORE WORK IS NEEDED ON LARGE AREAS TO DETERMINE THE RÔLE OF ANIMALS.

tions conducted by the Carnegie Institution of Washington indicate the kinds of research needed for the grasslands. They attack fundamental problems concerning the nature of the desert. The Desert Laboratory at Tucson, Arizona, is devoted primarily to this task; the view-point is wide and inclusive; the desert is considered in its widest relations to the environment. Intensive, as well as extensive, studies have been under way for a number of years. These basic studies are leading to a more complete knowledge of the desert fauna and flora and physical environment, and the knowledge gained serves with increasing value as a reservoir of facts and principles for the solution of practical problems. They are demonstrating that the most practical kind of investigation is fundamental research because it discloses basic facts upon which generalizations and principles may be built. Upon this wide and deep foundation of knowledge not only may an enormouse superstructure of scientific land use be erected, but also science and civilization in general may be advanced.

Notwithstanding that during the past thirty-five or forty years a great deal of study has been given to many of the phases of this complex subject by competent and painstaking investigators in widely scattered regions of great climatological variety, the surface of the subject as a whole can scarcely be said to have been more than scratched. Moreover, it would seem that, if the work of a group of different investigators could be coordinated, integrated and fitted into a common pattern covering a field limited to desirable proportions, much more valuable results would be attained than can possibly be secured from isolated individual efforts, however competent and painstaking they may be.

Such a thought as this occurred some

Photo by D. Anderson—Fargo, 1932
—Legend by J. A. Munro

DEAD GRASSHOPPERS ATTACHED TO GRASSES KILLED BY A WEATHER-CONTROLLED DISEASE

THIS FUNGUS DISEASE (EMPUSAE GRYLLI) ACCOMPLISHED NEARLY 100% KILL OF GRASSHOPPERS IN SMALL LOCALIZED AREAS WHERE HUMIDITY WAS HIGH. THE DYING HOPPERS ALWAYS CLIMBED TO THE TOP OF WEEDS BEFORE BEING OVERCOME BY THE DISEASE. HERE THEY REMAINED ATTACHED UNTIL REMOVED BY WEATHERING AGENCIES.

years ago to certain members of the Ecological Society of America. It appeared to them also that the great grasslands of North America, stretching from Saskatchewan to the Gulf of Mexico, would be particularly favorable for coordinated study. Accordingly a Committee for the Study of the Ecology of Grasslands was established by the society at the Cleveland meeting in 1929 and assigned the task of finding ways and means of effecting such an organization as would make possible the practical realization of the idea. Through the work of this committee the National Research Council became interested two years later and since then the committee has been sponsored in its endeavors by both the Ecological Society and the National Research Council. Under the competent and vigorous leadership of Dr. V. E. Shelford, who has done a prodigious amount of personal work, the committee has held a meeting at every subsequent Ecological Society meeting; it has held three regional meetings (Texas, June, 1933; North Dakota, June, 1935; Nebraska, June, 1937) and, in addition, has exchanged ideas and formulated principles continuously by correspondence. As a result of these deliberations, confidence in the soundness of the idea of cooperative, coordinated research has become stronger in the minds of all the committee members.

As desirable phases of the proposed study a recent report of the committee suggests the following, which it believes to embody a very high degree both of scientific merit and of practical applicability. Reasons for each subject of study recommended are briefly stated.[2]

(1) *Study of life history and habits of individual grassland plants and animals.*

[2] The numbered paragraphs were prepared by the committee during its 1935 meeting at Dickinson, N. D.; see 1935 Report, Part II, p. 11—deposited with the Division of Biology and Agriculture, National Research Council, Washington, D. C.

Photo by Elliot Blackwelder

GRASS IS MUCH REDUCED; SAGEBRUSH HAS INVADED

THE PRAIRIE MOUND-BUILDING ANT PERSISTS. ANTS AND RODENTS, NOT EARTHWORMS, ARE THE CHIEF SOIL WORKERS IN GRASSLAND. EASTERN WYOMING.

A

B

Photos by Herbert C. Hanson

C

SO-CALLED DESERT REVEALS ITS GRASSLAND CHARACTER

Knowledge of the life history and interrelationships of range plants and animals is meager. With plants there is vital need for further information on vegetative growth, methods and rate of dissemination, seed collections, etc. With animals detailed life histories and ecological and soil relationship studies are much needed. More serious than any other deficiency, perhaps, is the lack of information on plant-animal interrelationships, on food-chains, plant and animal succession, phenological features, factors influencing distribution and numbers of both plants and animals. The solution of these problems, affecting the biota as a whole and not plants or animals alone, is of extraordinary significance and permanent importance to the maintenance and increase of vital grassland values in soils, water, forage and wildlife.

(2) *Study of the processes of biotic communities, such as invasion, competition, association and succession.* Because of the lack of control of experimental areas and the insufficient duration of experiments, information on these processes is also meager. It is through these processes that eroded areas become revegetated, that over-grazed areas are rejuvenated and soil fertility restored. Only by studies of conditions in undisturbed areas can adequate controls be provided for experiments involving recovery.

(3) *Study of the relation of plants and animals to soil building, soil improvement, and soil binding.* This aspect includes the effect of various types of vegetation and soils on erosion, the nature of erosional resistance of various species and the relation between vegetation types and such soil conditions as acidity, alkalinity, structure, humus content, water content, salt content, etc. Fundamentally erosion control is dependent on vegetation in relation to soil type and topography. The influence of animals in the maintenance of porosity and productivity of soils has been greatly neglected. Seemingly the most favorable conditions for resistance to erosion have developed in native grassland which must be investigated in order to determine the factors controlling erosion and like destructive processes. Rodents are generally considered wholly bad. Only now are investigations being conducted with respect to their possible values in soil aeration and soil building, as a basic food for fur animals and as "safety factors" for game and live stock, and even as active agents (the beaver, for example) in erosion control.

(4) *Basic soil studies.* An understanding of soils, soil types and soil profiles as progressively modified by cultivation and other modes of utilization, and in respect to their organic reactions, can not be gained without continued comparative study of the soil and soil fauna normally present in undisturbed native grassland areas.

(5) *Study of the relation of vegetation and animal life to climatic conditions.* The native grassland must, therefore, be the basis of the study of the influences of precipitation, temperature, humidity, wind and light on plant and animal growth, behavior, distribution and populations. The normal grassland biotic community is the result of the attainment through a long period of development of a condition of equilibrium between the

DUE TO OVERGRAZING, SAGEBRUSH (ARTEMISIA TRIDENTATA) HAS INVADED MUCH OF THE WESTERN EDGE OF THE GRASSLAND, GREATLY REDUCING THE GRASSES, WHICH HOWEVER QUICKLY RETURN IF SEED PLANTS ARE AT HAND AND THE SAGE IS REMOVED. A. A COLORADO AREA IMMEDIATELY AFTER BURNING THE SAGE. SAGE BURNS READILY IN AUTUMN. THE MAN AT THE EDGE OF UNTOUCHED SAGEBRUSH MARKS THE POINT SHOWN IN FIGURES B AND C. B. SAME AS A, ONE YEAR AFTER REMOVAL OF THE SAGEBRUSH. C. SAME AS A AND B, TWO YEARS AFTER REMOVAL OF SAGEBRUSH. RODENT AND CATTLE EXCLOSURE LEFT; CATTLE EXCLOSURE RIGHT; LARAMIE RIVER VALLEY, NORTHERN COLORADO.

Photo by C. E. Williams

GRASSLAND BIRDS ARE FULLY EXPOSED TO THE SUN

A KILLDEER'S NEST IN THE WICHITA MOUNTAIN WILDLIFE REFUGE.

community and the climate in which it exists. The causes of annual variation in yield and nutritive value of forage and valuable game and other animal life can be determined. The variation and the causes of the beginning and ending of the growth period of most important plant species need determination. This information is of utmost scientific and practical value.

(6) *Study of the relation of animals to climatic conditions.* The data obtained from the studies mentioned in the previous section can be applied also to the study of variability in animal population from year to year. Fluctuations in abundance of animals are of great importance in the development of vegetation, and the converse effect of yearly variation in vegetation upon animal populations can not be overestimated. As stated above, the fluctuations in abundance of game animals are largely unexplained. There is a possibility that some of these effects may be due to variations in vitamin or mineral content of plant food. Such relationships require a great deal of investigation. In order to obtain results, records of fluctuations must be made over long periods of time and coupled with chemical and other related studies. The causes of fluctuations in numbers of insect pests on cultivated crops can not be determined without comparable data obtained from undisturbed grassland.

(7) *Study of interrelations between vegetation and grazing by live stock and by wild animals.* Thorough exploration under controlled conditions is needed in regard to range readiness, deferred grazing, rotation grazing, degree of utilization, frequency of grazing, determination by delicate indicators of over-grazing and palatability studies. Little of the present grazing literature on these subjects is based upon adequate research, largely because of the difficulties in securing sufficient areas of land and in providing for long-continued investigation, but also because of the absence of adequate checks on modifications of natural grassland communities.

(8) *Study of the interrelations of vegetation and biotic factors.* Under certain conditions rodents, which are often indiscriminately exterminated, may be more helpful than injurious because of their largely beneficial influence on the soil, their serving as food supply for valuable fur-bearers and their insectivorous habits. Evidence is accumulating that certain rodents increase in numbers under overgrazing. Similar relationships have been determined for certain species of grasshoppers, which are able to injure vegetation only under conditions of overgrazing. Little detailed work has, however, been done in the determination of such relationships and a great deal of information of value in the control of the animal components of the grassland communities may be gained. The possibility of cultured control has hardly been considered. Long-continued investigation on adequate experimental areas of native grassland is essential.

(9) *Studies of insects and the control of injurious species.* In grassland regions, most insect pests such as grasshoppers are native species, and measures for their efficient control must be based

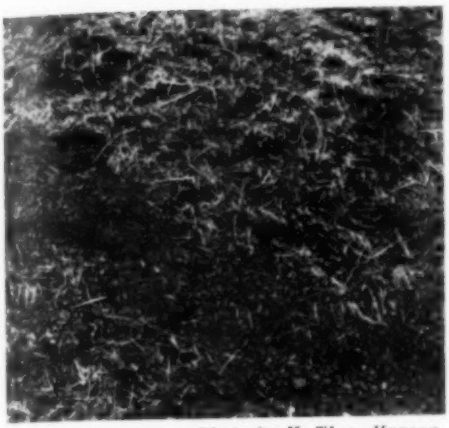


Photo by H. Theo. Hanson

CONCRETE EVIDENCE OF GRASSHOPPER ABUNDANCE

ACCUMULATIONS OF GRASSHOPPER PELLETS IN OLD RUT ALONG ROAD WASHED DOWN FROM HILLS BY RECENT LIGHT RAIN—ACCUMULATION ABOUT THREE INCHES DEEP. A FEW YEARS AGO IT WAS BELIEVED THERE NEVER WOULD BE ANOTHER GRASSHOPPER SCOURGE IN THE NORTH AMERICAN GRASSLAND. WESTERN NORTH DAKOTA.

Photo by F. A. Morton, U. S. Bureau of Entomology

GRASSHOPPERS TAKE FORAGE

GRASS QUADRAT PROTECTED FROM GRASSHOPPERS. BAXTER RANCH, HARLOWTON, MONTANA.

upon exact knowledge of interrelationships, behavior, life history and protection in the natural environment. In this case also control by cultural methods versus chemical means promises possibilities of large savings and more effective results.

The above-mentioned studies, in order of their apparent importance and feasibility, the committee would inaugurate, as means permit, in Saskatchewan, North Dakota, Nebraska, Illinois, Iowa, Oklahoma, Arizona and Texas under the direction of the biological departments at the universities of these respective states.

The nature of the general problem of administration, in the minds of the committee, is such as to render it much more likely of solution under an endowment administered by a single coordinating board acting in cooperation with the governing boards of the several institutions than it could possibly be if these several institutional boards attempted to set to work without such a coordinating body. It is hoped that the great merit of the problem will be sufficiently apparent to constrain the endowment necessary to materialize the idea into an effective working system.

It is realized that so extensive a program, applicable to grasslands of diverse types, may not be possible of immediate realization. The committee has therefore given consideration to a simpler plan contemplating the initial establishment of a single centralized study center, probably in western Nebraska or South Dakota, where there is hope of cooperation with the federal government.

Another serious need is primarily educational. Unlike many of the universities in the forested sections of North America, which have tracts of forest land available for research conducted by the faculty and for training of research workers and teachers of forestry and land use, the universities of the grassland states now have no equivalent facilities. The extensive grassland studies of the University of Nebraska and the noteworthy work in other midwestern universities have been conducted on leased lands. Unfortunately, the breaking up of such lands by the plow has often interrupted actual studies and made long-time observation impossible. The acquirement of lands close to these educational centers is greatly to be desired.

THE MOUNT EVANS LABORATORY

By Professor J. C. STEARNS

UNIVERSITY OF DENVER

THE construction of Mount Evans Laboratory was begun in May, 1936, and the laboratory was first used for scientific work on June 28, 1937. For those whom this laboratory may serve, the following description of the location, climate, physical plant and policy of operation of the laboratory, as well as the events leading to its establishment, will be of interest.

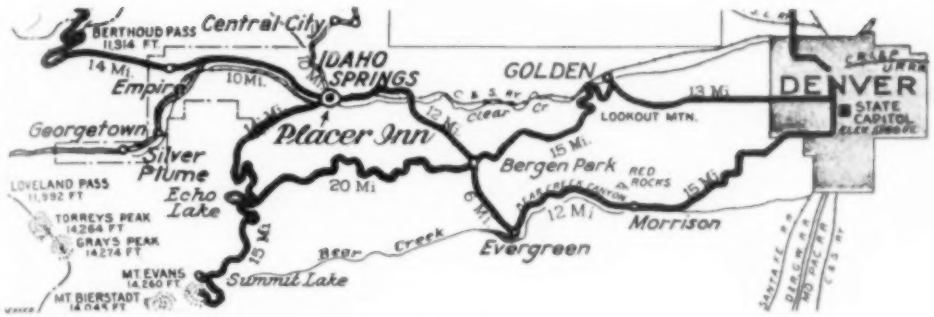
In September, 1931, A. H. Compton did his first field work in cosmic rays at Summit Lake, which is 1,000 feet below the peak on Mt. Evans. Cosmic ray intensity measurements were made on Mt. Evans for a brief period at this time. The apparatus used was constructed at the University of Chicago and transported to Colorado in an enclosed bus, which served as a cosmic ray laboratory for this first work. The rigors of the climate were such that, with the lack of adequate protection, a trick on the night shift was equivalent to a polar expedition. This expedition was followed by others headed by R. D. Bennett, Massachusetts Institute of Technology; T. H. Johnson, Bartol Research Foundation; J. C. Street, Harvard; D. K. Froman, McDonald College of McGill University; and J. C. Stearns, of the University of Denver.

These early workers and their associates used tents for laboratories and living quarters. The wind velocity at night was often sufficient to level tents and scatter equipment. The fire hazard prevented safe heating of tents, and the indoor temperatures often fell to 30 degrees F. or lower. Both apparatus and workers were without protection from the frequent electric storms.

The intensity of cosmic rays at the alti-

ECHO LAKE LODGE

FIFTEEN MILES FROM THE MT. EVANS LABORATORY.



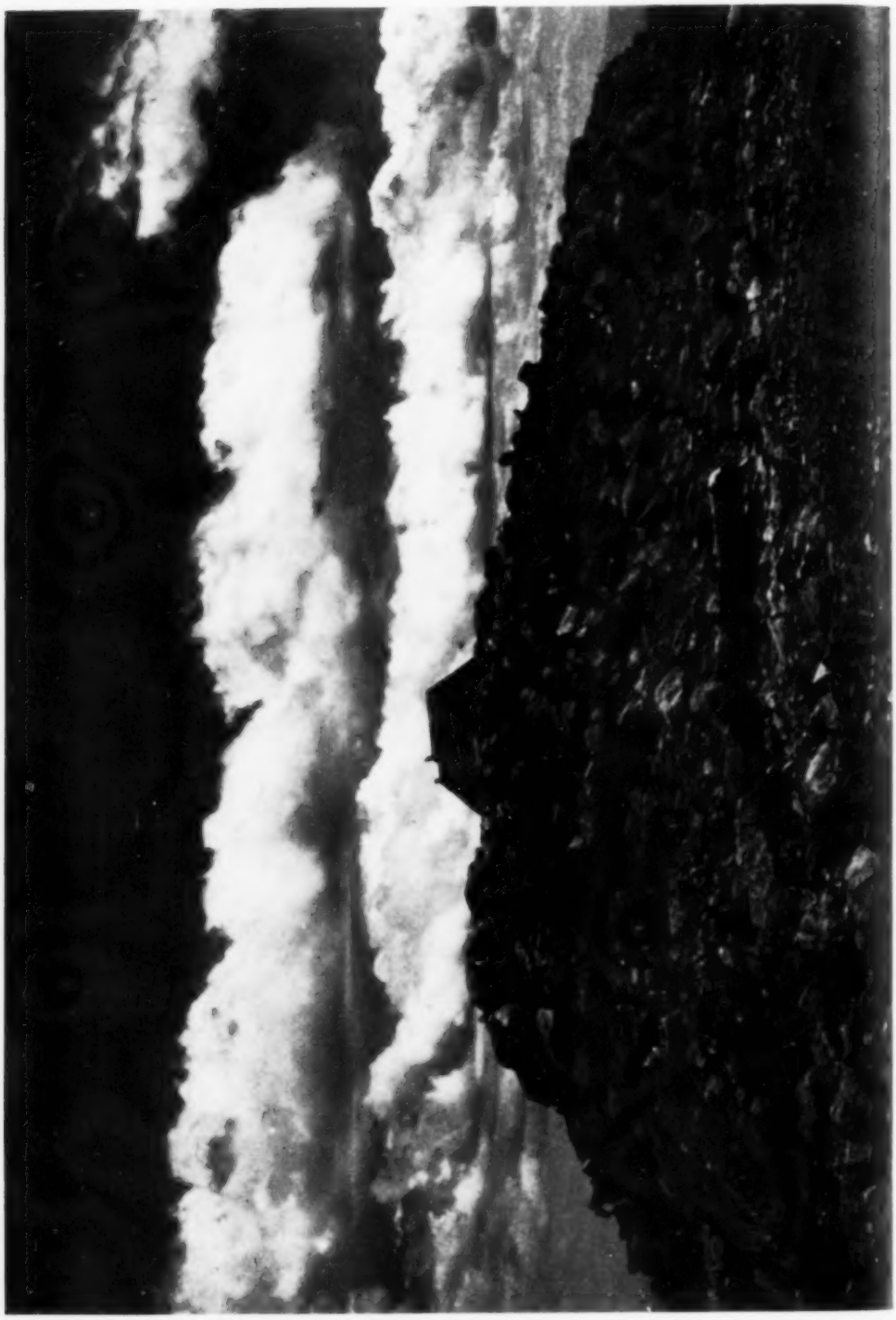
MAP SHOWING LOCATION OF MT. EVANS
SUMMIT LAKE, ECHO LAKE AND IDAHO SPRINGS.

tude of Mt. Evans (14,260 feet) is five times that at sea level, offering an opportunity for a corresponding increase in the rate of collection of data in some aspects of the studies. However, it was evident that if any prolonged or accurate observations were to be made, some sort of adequate shelter must be provided for workers and apparatus. Dr. K. T. Compton, president of the Massachusetts Institute of Technology, and Mr. John Evans, an alumnus of the Massachusetts Institute of Technology and chairman of the board of trustees of the University of Denver, investigated the possibility of erecting a suitable building for this purpose. The result was a project sponsored jointly by the Massachusetts Institute of Technology and the University of Denver.

Location

The following considerations led to the selection of Mt. Evans as the site for the

TIMBERLINE TREES
NEAR THE MT. EVANS HIGHWAY, ABOUT TEN MILES FROM THE LABORATORY.



LABORATORY AS SEEN FROM THE TERMINUS OF THE AUTOMOBILE ROAD

laboratory: (1) It is the highest easily accessible mountain peak in the United States. (2) There are living accommodations on the Mt. Evans highway at altitudes of 10,600, 8,000 and 6,000 feet, respectively. (3) Mt. Evans is located near a city where scientific apparatus and supplies may be secured. (4) It is located near two universities, whose staff members are engaged in experimental work in cosmic rays.

Mt. Evans is 65 miles from Denver, at the terminus of the highest automobile road in the United States. The altitude of the peak, 14,260 feet, and about 2,500 feet above timber line, affords a clear horizon in all directions. The nearest available hotel is Echo Lake Lodge, at a distance of 15 miles by road and at an elevation of 10,600 feet. Idaho Springs is the nearest source of supplies and is 29 miles by road from the laboratory.

Climate

The barometric pressure averages about 45 cms. and the temperature during the summer months varies from 15 degrees to 70 degrees F. Though the wind velocity is sometimes excessively high and there are frequent afternoon sleet and snow storms, the mornings are often calm and clear. At times the electric poten-

TRAILING THE INVISIBLE

GROUP OF PHYSICISTS ATOP MOUNT EVANS, THREE MILES ABOVE THE SEA, MEASURING COSMIC RAYS. FROM LEFT TO RIGHT: WILCOX OVERBECK, UNIVERSITY OF DENVER; DR. J. L. DUNHAM, OF HARVARD UNIVERSITY; DR. RALPH D. BENNETT, OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY; DR. ERVIN H. BRAMHALL, OF CAMBRIDGE UNIVERSITY, ENGLAND; DR. JOYCE C. STEARNS, OF THE UNIVERSITY OF DENVER.

LABORATORY AS SEEN FROM THE TERMINUS OF THE AUTOMOBILE ROAD

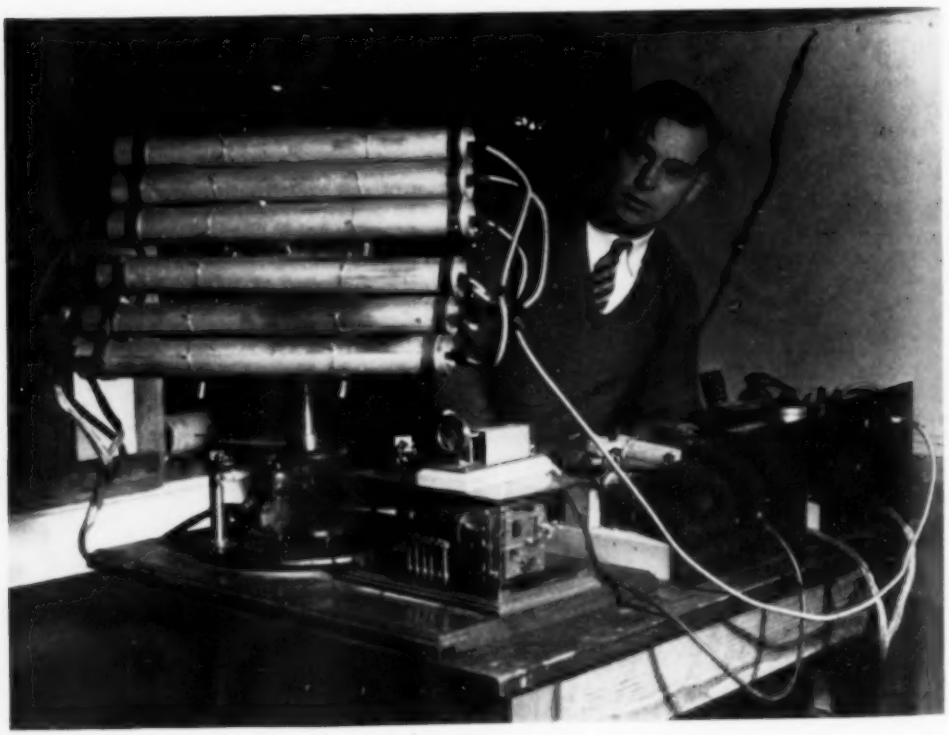
tial gradient is high enough to produce marked corona discharges from rocks and other projections, including persons. The weather is usually milder in August and September than in July. There is seldom a day which does not present a sample of all the seasons except midsummer at the lower altitudes.

The Physical Plant

The laboratory consists of two rooms, each having a floor space 21 by 24 feet, with a height of 11 feet at the center, one room being used as a laboratory and the other for living quarters. Six permanent cots and mattresses of the submarine type are provided, and additional folding cots are available should they be required. There are also tables, chairs, stoves and other necessary household equipment. A 500-watt, 60-cycle, 110-volt, gas-engine driven generator is housed in the laboratory.

To withstand the high wind velocity, a roof truss construction was employed, which made the omission of side walls possible. Cables fastened to the floor joists run through the pillars of the foundation to heavy metal plates cemented into the rock. The building is thermally insulated and is easily heated. Louvres provide "no draft" ventilation.

For protection against lightning, the end walls and roof are covered with thin copper shingles, and the lower side of the floor is covered with metal hardware cloth. The copper and hardware cloth are joined and earthed, thus converting the whole building into a Faraday cage. The copper of the roof is not thick enough



GEIGER COUNTER TELESCOPE
USED IN MT. EVANS LABORATORY, SUMMER, 1937.

ROAD LEADING TO MT. EVANS LABORATORY
WHICH IS 200 YARDS FROM THE TERMINUS.

to materially interfere with cosmic ray measurements.

Many people and government agencies cooperated in the constructing of this laboratory. Mr. Burnham Hoyt, the architect, was responsible for the unique plan. The building was pre-fabricated in Denver, sawed into sections, and then transported to Mt. Evans by a caravan of trucks furnished by the City of Denver. George E. Cranmer, superintendent of Denver Mountain Parks, helped to secure this excellent assistance. The sections were carried from the terminus of the automobile road to the building site on the peak by CCC labor, assigned to the Forest Service of this region. Permission to erect the laboratory at this location was granted by the Forest Service of the United States Department of Agriculture. Colonel Allen S. Peck, of the U. S. Forest Service, cooperated fully in securing this invaluable aid from the United States government. Mr. T. F. McKay, the builder, worked under severe weather handicaps and without profit to produce the excellent structure.

Experimental Work, Summer, 1937

The following projects were carried out during the initial year of the laboratory: Professor Victor Jollos, of the University of Wisconsin, investigated the possible mutations produced in Drosophila by cosmic primary and shower radiation; Professor Fred D'Amour, of the University of Denver, studied the effect of shower radiation, produced in lead, on the reproductive processes in rats; Professor D. K. Froman, of McGill University, and Professor J. C. Stearns, of the University of Denver, studied the variations in cosmic ray showers produced in different metals, and the effects produced by different thicknesses of the same metal. It is interesting to note that while these biological and physical investigations originated independently, the work became a cooperative one to the extent that the adequate interpretation of biological effects required the data which were obtained in the physical experiment.

Professor T. R. Wilkins, of the University of Rochester, continued his inter-

SHELTER HOUSE AT SUMMIT LAKE. MT. EVANS IN THE BACKGROUND
SEVERAL EXPEDITIONS UTILIZED THIS FOR EARLY MEASUREMENTS ON COSMIC RAYS.

esting work on particle tracks in photographic emulsions which was begun before the laboratory was completed. Emulsions which permanently record the tracks of ionizing particles were exposed for six weeks in the laboratory.

Purpose and Availability

Though the beginning is a very modest one, it is hoped that this laboratory may grow to serve the United States as well as the Jungfrau laboratory serves Europe. To that end the physical plant will be enlarged and improved as the demand warrants. With this in view, Mr. Burnham Hoyt has prepared very interesting plans for a more adequate laboratory if and when there are indications that a demand for such additional facilities exists. The present laboratory is available at the small cost of operating expenses to qualified workers in physics, meteorology, astrophysics, biology and other sciences who wish to carry on experiments at this altitude.

For the 1938 season, if snow conditions are normal, the road to the laboratory will open about June 25, and remain so until late September. The laboratory may be reached at all times of the year on snowshoes over the fifteen miles from Echo Lake, the limit to which the road is cleared in winter. Those contemplating working at the laboratory should make arrangements well in advance with Professor J. C. Stearns, of the University of Denver.

MAN'S ANCESTRAL HOME

By Dr. HERVEY W. SHIMER

PROFESSOR OF PALEONTOLOGY IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, FELLOW OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES

WHAT is the region and what the environment in which man became differentiated from other animals and became *man*? In other words, what is his ancestral home?

In searching for the answer to this question, we are led to the consideration of when the human stock arose, and from what remote ancestor. It is generally held to-day that man and the living anthropoid apes are very closely akin, and that they have probably arisen from a common ancestral stock. Every bone of the skeleton of man, nearly all his muscles, nerves and blood vessels, the arrangement of the viscera, the placenta, and many other characters, are fundamentally identical with those of the living anthropoid apes.

Human ontogeny, moreover, indicates such relationship. During the early foetal stage (fifth to sixth week of embryonic life) the bodily proportions of man and the higher apes are very similar. From this time to maturity they diverge. In the early foetal stage of both groups, the arms are much longer than the legs; in the adult apes this condition in general is retained, while in man the legs lengthen greatly in proportion to the arms. The human nose becomes higher and narrower from the early foetus to the adult; in the adult ape it remains near the foetal condition. From a similar condition of thumb and hand, the apes have developed the hand into a hook-like grasping organ, with a degeneration of the thumb, while man has retained the broad hand and has developed the thumb into a tool-making instrument.

It is thus seen that while man and the living anthropoid apes have probably descended from some common ancestor, man could not have evolved from any of the living apes. Each line has become too specialized. In the narrow hand with hook-like fingers and reduced thumb, apes have passed beyond the more generalized hand which they possess during their embryonic development and which man carries on into adult growth. It is, accordingly, not in the habitat which apes find congenial that we should look for the environment which would promote the evolution of early man.

How long ago did this divergence take place? The divergence of a common ancestral stock into anthropoid apes and man must have begun at a time sufficiently remote to permit of the vast changes which now distinguish the adults of the two groups. The few thousand years of historic time have witnessed slight changes in man's body. Even the human being of mid-glacial times, 500,000 years ago, differed not very greatly from modern man, mainly in skull and lower jaw and less erect posture. Man of even early Glacial time, a million years ago, had diverged vastly from the ancestral anthropoid stock, as indicated in the ontogeny of both man and apes—a divergence seen in the relative length of arms and legs, the shape and size of hands, fingers, feet and toes, the change in height of forehead, length of face, length of nose, the uprightness of the body, the curvature of the backbone. This great length of time since our common ancestor lived his life in the environment we are trying to picture is indicated likewise in the changes that living anthropoid apes have developed from the ancestral stock.

The extinct anthropoid ape that most satisfactorily combines the characters of apes and man which we consider this common ancestor to have possessed is Dryopithecus. He was a tree-dwelling anthropoid, as large as a chimpanzee. The canine teeth forecast the human in their relatively small size, not fang-like as in the adult modern ape, but more like the teeth of the young ape or of adult man. This genus is known from the Miocene and Pliocene of Europe and Asia. Some species are closer to man and some are closer to the chimpanzee and the gorilla. The molar teeth, which are so often the paleontologist's chief dependence in tracing relationships among the vertebrates, show certain arrangements of cusps and grooves on their grinding surface. The pattern of these in Dryopithecus is least modified in the Upper Pliocene man of Piltdown. It is retained in the youths of the later Pleistocene races but becomes obscured in maturity. The living adult apes, on the other hand, have retained the pattern with divers slight modifications, while adult modern man has departed from it most widely.

From these and other considerations, it seems that Dryopithecus, most closely of all fossil apes so far found, embodies our ideas of the remote common ancestor of both apes and man, which means that it is back to some region as it was during the Miocene, some twenty million years ago, that we look for man's ancestral home.

Our search is conditioned by the sort of environment which as a stimulus acting on innate organic changes, would initiate, or at least promote, the divergence between apes and man. Constant though slow variation is characteristic of all life. In certain groups, however, change is more rapid than in others. Whatever the causes of these changes, whether internal or external, there is little doubt that the environment acts as a pruning knife, cutting off those individuals and species least adapted to it.

If man is descended from the tree-dwelling Dryopithecoid or nearly related stock of large anthropoids, the problem is, what sort of environment would promote the divergence of this stock into the present tree-dwelling apes and ground-dwelling man. A very strong impetus and a most efficient selective factor must have operated to force the man line out of the comparative safety of the trees to the untried vicissitudes of life on the open ground. Even to-day man does not change his habits except under compulsion. The only cause which investigators at present consider of sufficient force to have brought about this change in habit is the slow, gradual transformation of the large wide-spreading forests of a humid region into the almost treeless condition of a semi-arid region. The individuals which could survive under such slowly changing climatic conditions would be those which developed in the direction of becoming ground runners, first to go from grove to grove, and as a next step, to use the trees only as places of refuge.

A tendency to increase in size is manifested in most families of animals. The lines of the horse, camel, rhinoceros and elephant began with very small animals. Man's own line, the Primates, began with animals about the size of small rats, and has reached to-day the size of ground-dwelling man and the semi-arboreal gorilla. A sufficient increase in size, however, to leave man less at the mercy of enemies on the ground would, on the other hand, prevent him from leaping freely through the trees. Hence he would need to live to an increasing extent upon the ground.

The great development of the forebrain in the early anthropoids had forced upon them a semi-erect attitude for forward looking. Hence in living upon the ground they would become more and

more erect. Long legs are an advantage to a running animal, as is seen in the evolution of the horse, the deer and the ostrich. Animals which developed longer legs, other things being equal, would survive longer and thus have a greater number of offspring. Hence in succeeding generations of human beings life on the ground would promote an increase in the proportional length of the legs. That the ancestors of present-day man developed running ability rather late in the geologic time is shown by the fact that in man the increased length of leg over arm takes place after birth, for at the age of a month the human baby has leg and arm of equal length.

In the foot, too, though dissection of the muscles shows that the foot of chimpanzee and gorilla is operated by muscles which correspond to those in the human foot, yet the human foot has been modified by long ages of running on the ground, so the great toe is longer, the outer four toes have become shorter, and all are drawn inwards towards a median line. A tendency towards increased length of one or two toes and the reduction of the others is seen in all running animals; note the ostrich, horse and deer. The anthropoids, which continued living in trees, on the other hand, have retained the spreading toes, with the great toe projecting like a thumb.

Life upon the ground, with an increasing uprightness of body, would induce a change in the profile of the backbone, and likewise tend to develop a more flexible and opposable thumb. For the hand, freed from use in walking, could be utilized in lifting objects up to the face and turning them about for examination. Those individuals in which the cerebrum was enlarging most rapidly could take most advantage of such examinations and be most prepared to survive in this new habitat on the ground, this habitat that would demand quick thought and rapid decision.

Just as it has been shown that a region undergoing increasing aridity was the theater for the evolution of such a cursorial animal as the horse, so this running ability of man points to a region of increasing aridity as the probable theater for early human experiments. What of the region and time of this change from ancestral anthropoid to man? Where was man's ancestral home?

We naturally look for an answer to three lines of evidence. First upon what continents and during what geologic times did the ancestral stock live? Second, where have the earliest remains of man been found? Third, where, upon these continents and at the requisite time in earth history, is there evidence of a change from a forested to an almost treeless condition, and in a region sufficiently extended to provide space for all the interactions taking part in such an evolution?

First, as to where and when man's ancestors lived—or rather those lines that are supposed to have been ancestors. *Dryopithecus*, belonging to such an ancestral stock, or at least representing a close relationship, has been found only in the Miocene and Pliocene of Europe and Asia. The fossil skull from South Africa, known as the Taungs infant, is also pertinent to this query. This skull has some characters which relate it to man, but more relating it to the chimpanzee-gorilla line. It is difficult to evaluate the skull of an infant in terms of an adult, since an infant possesses ancestral characters which it loses during its growth to maturity. This skull, however, points towards a common ancestor of apes and man. Its age, as given by Broom, who described the associated fauna, is Lower Pliocene, though Dart and Keith consider it as Miocene.

Thus fossil evidence of the common ancestor of man and the apes has been found in Europe, Asia and Africa, and lived during the Miocene and Pliocene.

As to our second query, the earliest remains of man himself have so far been found only in Europe and Asia. These oldest skeletal remains are: *Eoanthropus* (the Piltdown man) from the late Pliocene or earliest Pleistocene of southeastern England; *Sinanthropus* (Pekin man) from early Pleistocene near Peiping, China; *Pithecanthropus* (Trinil man) from the early Pleistocene of Java, and *Paleanthropus* (Heidelberg man) from the mid Pleistocene of southwest Germany. These four extinct genera of primitive man occur on the periphery of the Euro-Asiatic land mass.

Now Matthew has shown that the most primitive members of a group of animals are those that are found farthest removed from the center of the evolution of that group. For a center of dispersal is the place where evolution is at a maximum. Those individuals that can not compete here are forced away from the optimum habitat and try to adapt themselves to less than optimum conditions. If this original center became, for example, too arid for an optimum habitat, other centers of dispersal would develop in other regions of more favorable climate and food supply for that particular group of animals in their particular stage of evolution. Applying Matthew's generalization to the dispersal center of earliest known man would place it somewhere in central Asia.

North and South America may be omitted from our consideration, since no fossil anthropoids have been found on either continent and their more distant relatives, the New World monkeys, that are found here, are built on a different plan, which shows that they are an earlier offshoot from the Primate stem. All fossil human remains that have been found in the Americas belong to the stage of living man, *Homo sapiens*.

The ontogeny of man, that is, his growth from the foetal stage to adulthood, indicates an ancestral change from an arboreal habitat to life on the ground. So our third line of inquiry is concerned with the search for a locality where man would receive the stimulus to change from an arboreal to a ground habitat. Probably the only compulsion of sufficient strength to bring this about would be a change in climate from humid to semi-arid. And such a change would probably have been due to the rise of a mountain chain across the course of the moisture-bearing winds. What regions in the Old World fit such an hypothesis of changing climatic conditions in mid to later Tertiary times?

Europe may be rejected as a possibility. This continent receives its principal rain supply from the Atlantic Ocean, and since no mountain chain extending in a north-south direction was upheaved in western Europe during mid or late Tertiary, its climate has remained rather stable.

In Africa the problem is more complicated. There are no mountain chains of mid Tertiary or later origin to cut off moisture-bearing winds, but during the later Tertiary the continent was elevated, and this tended to reduce the number of trees in certain inland areas. At present, however, it seems doubtful if there is sufficient evidence to include any part of Africa among the candidates for man's ancestral home.

It is in Asia that we find most fully exemplified the required climatic conditions occurring at the right geologic time to fit the fossil evidence. At the close of the Oligocene the Himalayan mountains had their first period of folding and elevation. The Siwalik geosyncline, formed at their southern margin and filled with Miocene and Pliocene sediments, gives evidence, in the uniformly coarse sediment from bottom to top, of the continued rise of the Himalayas during this time. After the Pliocene these Siwalik sedi-

ments, 16,000 feet thick, were folded, forming the Salt Range, accompanied by a further elevation of the Himalayas and the formation of the Indo-Gangetic geosyncline along their southern margin.

It is thus seen that the Himalayan ranges, beginning to rise at the close of the Oligocene, continued to be uplifted at intervals during the Miocene and Pliocene and Pleistocene times. The rising of these east-west trending mountains tended to shut out more and more completely from their northern side the monsoon rains from the south, practically the only source of moisture in this region.

During the Oligocene, the Tibetan and adjoining regions to the east and west, and north probably to parallel 50°, were apparently low lying, well watered and heavily forested. Coal beds of this age in Manchuria contain such deciduous trees as Populus, Carpinus, Alnus, Dryophyllum and Fagus, and such conifers as Sequoia and Glyptostrobus. These forests probably covered all central Asia, with the incoming of some warmer temperate trees in southern areas, such as Tibet; but no plant fossils have as yet been found in the southern part of this area. The region was apparently well drained; that it was forested is shown by the presence of such mammals as the colossal rhinoceros *Baluchitherium*, as large as an elephant. This animal could not have crossed deserts or high mountains, yet its remains are found from Baluchistan through Russian Turkestan, Mongolia and Ordos in central China.

We find here, then, in southern Asia all the postulated requisite conditions for the evolution of man from a generalized anthropoid of a type very similar to *Dryopithecus*. Moreover, this genus has been found in this area in the Siwalik sediment of Miocene age.

If southern Asia was man's ancestral home, we may conceive members of the Dryopithecoid or nearly related stock as occupying the region from southern India north to beyond Tibet. From this territory they probably migrated to some extent north or south with the seasons, thus facilitating mixture between the more virile temperate tribes and the less progressive tropical tribes.

Man, like any other animal, develops most rapidly where he must use all his faculties, physical and mental, to survive. If the temperature is so low or the food so limited in quantity and variety that the physical body must use all its energy to maintain itself, no energy remains for mental development. When, on the other hand, the temperature is high and the food plentiful, there is only slight compulsion for either physical or mental activity. Hence it is to a temperate climate that we must look for the scene of man's evolution.

We may, then, postulate man in his ancestral home at the close of the Oligocene some twenty to thirty million years ago, unconsciously affected by the beginning of the elevation of the Himalayas. The winds from the Indian Ocean, bearing moisture to the forests of his homeland, were, during the successive ages, increasingly intercepted by this rising land mass, and less and less of the moisture reached the northern slopes. The water table consequently sank and the forests slowly disappeared.

During this long time many changes would be taking place in the ancestral anthropoid stock; for the Primate order, to which man belongs, is like the ungulate and carnivore orders in being subject to rapid evolution throughout Cenozoic time. Those individuals which developed characters which were advantageous in a region of decreasing forest cover and numerous ground-living enemies would survive more frequently than those less favored. That is, as the formerly continuous forested areas became divided into separate groves, these anthropoid

ancestors of man, caught to the north of the mountain barrier, would be forced to run from one grove to another in the search for food, and thus be forced out of the comparative safety of the trees. As the groves became smaller and more distant from each other a rapid elimination of the slower-witted and less agile members must have taken place. Those with longer legs and larger brains would survive most frequently. The curve of evolution would, accordingly, be in the direction of brain and speed.

In our search for man's ancestral home, we are left with much uncertainty and many unanswered questions. The strata of south central Asia are a vast and largely unexplored treasure chest. It may well be that from them future investigators may learn if it was assuredly there that the human stock arose, and, if so, in what environment of plants and animals the first men lived their lives.

And so as we look back down this tremendously long and poorly lighted avenue of years, it must be largely with the eyes of the imagination that we see this half-human ancestor of ours. Instincts and vague gropings and hungers from within, meeting the menaces and challenges of the environment without, would keep the slow brain active. The search for food and the avoidance of carnivorous enemies would put an increasingly valuable premium on larger brains, longer legs and better hands. Safety depended on being an animated question mark. Since asking questions is still a human characteristic, it is still as a question that I leave this subject of man's early home.

EXPLORING A REALLY "NEW" WORLD

By ERNEST INGERSOLL

NEW YORK, N. Y.

THIS essay seeks to show how America first became explored and gradually occupied by immigrants from Asia, who came across Bering Sea and then spread southward; it is based on undisputed facts, reviewed in the light of imagination. Initially, however, boats similar to those made by modern Eskimos (frames of wood or whalebone covered with sewn skins of walrus or seal) brought the earliest comers to the shores of this continent and were used as long as men remained within the Arctic Circle, where alone the hides of those animals were obtainable. Southward of that region, the only boat possible to the means and ability of these visitors was one shaped of wood. Unless they could provide themselves with this means of transportation as they moved along, the primary exploration and possession of a totally unknown and vacant continent, furrowed by rivers, was virtually impossible; inasmuch as the amazing project of these immigrants was accomplished by its aid, the wooden canoe has become enshrined in the history of human life on this continent. Therefore, it is worth a moment's attention.

The earliest human beings imaginable must have been associated with rivers and other bodies of water, and have ventured to enter them and make more or less voluntary efforts to swim. When imperiled by sudden floods or other mishaps they would try to save themselves by seizing drifting logs or lesser bits of wood. Animals constantly do so. A youth might thus mount a floating log and, by paddling with hands and feet, manage to guide it; but round logs are tricky, while flat pieces are safer. When these proto-humans had acquired the means of doing this they would next trim and flatten a chosen log, at least on top, and so be able not only to sit on it securely, and move it as they pleased by means of a pole or a leafy branch or a piece of bark, but also could carry something with them. Such a deck-load would be less likely to fall off were the top of the log somewhat hollowed; this done, the first step has been taken toward the one-piece canoe, naturally named a "dugout."

A dugout, then, is a sound tree trunk or log hollowed into a trough and otherwise shaped into usefulness as a boat. The form may vary as the purpose, materials and adaptive skill of makers differ, but the *type* is fixed, all over the world, by the very nature of its structure and conditions and character of usefulness. Undoubtedly it, or at least the art and method of making it, was brought by the first human persons to set foot on this continent—men who came across the Bering Sea from the northeastern extremity of Siberia. Indexed by its highest examples in workmanship and in fitness for local requirements, *the dugout may be considered the one perfected product of human thought as an instrument of service.*

This momentous event may be roughly placed at twelve thousand years ago. At that time the stupendous glaciation which had buried much of the northern hemisphere had melted sufficiently to release eastern Siberia, and also the western half of the area of the United States of America, from its deadly grasp. Thanks to the warming influence of the Japanese current probably both shores of the North Pacific were soonest freed of ice—at any rate, vegetation and animal life could

occupy them. Long before that time southern and eastern Asia appears to have become populated; gradually southern Siberia was overspread by humanity; and at last men had spread, perhaps by force rather than device, even to the cold and desolate seashore of Kamchatka where they were compelled to subsist almost wholly on fish and marine animals and birds. Pushing, or pushed, on northward they finally reached the Arctic coast and wandered out upon East Cape, from whose hills distant land could be seen beyond the icy or tempestuous waters of what we now call Bering Strait.

No place as a home could be worse than where these forlorn men and women were; was it not possible, they must have asked each other, that the mistily notched horizon, possibly islands, held better conditions for human existence? One may feel certain that soon certain energetic souls among these brown-skinned Mongolians—if so they were (?)—led by curiosity and hope, crossed the strait in skin boats, or by foot on winter ice, and landed where there were plains like those they had left—or better. Returning, they told of herds of seals and walruses easily accessible, of game plentiful and incredibly tame, of marvelous flocks of birds and annual supplies of eggs inexhaustible; of new and plentiful fishes and whales. Other scouts followed, went farther and farther southward along the coast, and came back with a report that made previous advantages seem small—rivers crowded with *salmon!* That, more than anything else, established the attractiveness of the new land. Well did the Siberians know this precious food-fish, and the knowledge that it abounded there encouraged the most timid to seek a home on the opposite shore, so that in a relatively short time a colony or village—men, women, dogs and gear—was established on the blank beaches of Alaska.

Such was the planting of the seed that was to populate the New World and bring into existence a new class of mankind—the American Indians.

These ancestral immigrants, although perhaps as poor specimens of Asiatics as could be found, were not wild savages, "cave men" of the Paleolithic Age. They were well in advance of it, for they had attained to some skill with tools, an acquaintance with certain domestic animals and the rudiments of agriculture, and their descendants never rose much higher until Europeans supplied them with, and taught them the uses of, iron and horses. Theretofore articles and implements of stone and bone, sea-shells, wood and leather fulfilled the mechanical requirements of their simple lives.

Awakened by what in their boldness had already been accomplished, these hardy exiles set themselves to learn what remained of possible betterment. The almost barren *tundra* furnished them some food and caribou and bird skins for clothing, but otherwise held neither attraction nor promise. Hopefully exploration continued southward, afoot and by boat and dog-sledge. The ever-searching scouts reported little either helpful or harmful, and had always to answer "No" to the eager question, "Did you see any men?" Who can estimate how many years or centuries elapsed before discovery was halted by the Yukon River, miles wide so near its mouth! Many generations before this the original landing-place at the tip of Seward Peninsula had been abandoned, and most of the enlarging population had moved southward and now were gathered by the Yukon, and were building huts and fishing-stands. The banks were lined with drifted logs, from which big canoes could be carved, and in them, in the course of time, young men ascended the river until they sighted ranges of dreaded mountains, then turned back to make report and to advise their friends against any movement in that direction. No sight or sound of any human being had disturbed

the solitude of the valley or relieved the voiceless loneliness of the dreary coast. Awe-struck grayheads declared the country must be bewitched; young men and women retorted, "At any rate it is *ours*," and determined to follow the sun toward the south.

Let us suppose these Neoliths stayed near the Yukon until they had doubled or trebled their numbers, yet, if so, a drifting southward must have soon begun. This was inevitable, for food was obtainable there for only a limited congregation of people, and the only path open lay between the mountains and the sea. That moving became a migration, ever pressed forward by its own weight, even though it left behind it a thin string of tiny settlements.

What a progress that was—compulsory, unguided, stumbling, halting, going on none knew whither or why! Did hope revive when they came to the forests of southern Alaska, or were they dismayed by what they had never seen before—masses of trees, amid whose shadows lurked dangers real and imaginary, chilling the heart of the boldest of men. On the other hand, think of the excitement, if not joy, of the succession of new scenes and experiences that were constantly met! No possible information was accessible to them save through their senses. Nobody was here or ever had been to tell them what lay even a day ahead, or leave the slightest record for guidance. Their forefathers had never seen two trees together; and who were these forefathers? They had forgotten hundreds of years before—stories of mythical happenings and hero-tales of mixed men and animals made impossible traditions. Yet we must believe that their minds were awakened anew and grew year by year as they struggled to advance through difficulties, rigors and fears almost inconceivable, as they crept along the hundreds of miles of Alaskan seacoast. Minds were stimulated, bodies strengthened, and only the "fittest" survived; but none could have gotten through had it not been for their dugouts!

At last, no one knows when, these migrants were safely cruising, or pleasantly marching, along the warm "inland passages" beside the British Columbian coast. Even so they found there little change in geography or resources as they advanced, lured by the softening climate and the habit of pressing forward; but hope was fading. Countless generations had lived and died, held as in a vise between an inexorable ocean and impregnable mountains. Would the gods ever free them from this narrow prison? Such an expectation seemed vain.

Then with almost startling suddenness the mountains stepped back, and a wide, beautiful space opened before their weary eyes and feet—the shining expanse and gently sloping shores of Puget Sound. Here was warmth and rest, abundance of food and comfort, every benefit except companionship. No human cry answered their hail, no glare of flame or signal-smoke aroused response, no enemy contested invasion. Here must have slowly accumulated the first considerable stoppage of marching and a gathering of migrant bands; and it is logical to believe that here a village soon arose to become a persistent nursery and a center of distribution of the American race ten thousand years later labeled "Indians." The formidable continental forest grew to the margins of the Sound, firs, cedars and their ilk two or three hundred feet tall rising from a nearly impenetrable undergrowth. A little way beyond, however, was an open, grassy space, the Nisqually Plains, and this may have been the site of the settlement. We may also feel certain that a limited area by the water was gradually cleared by means of fire and stone hatchets, and that from the enormous logs of drifted or fallen trees began to be carved forerunners of those big and graceful dugout-canoes, after-

ward known as "Chinooks," that became the pride of the Northwest.

While this assemblage of lodges and their residents grew in size and importance, continual arrivals of migrants from the north made it, as I have imagined, into a nursery of a new race. This race was still in its Stone-Age childhood, but it had intelligence sufficient for its immediate necessity, and improvable as stimuli appeared. I try not to magnify these Neolithic "children," but their descendants formed the League of the Iroquois, erected the astonishing structures and philosophy of the prehistoric Mexicans and bred the dynasty of the Incas of civilized Peru. Those were the products of self-developed brainwork.

Meanwhile, inspired by the inbred, forward-looking curiosity and spirit of the tribes energetic leaders soon began warily to penetrate and examine the region ahead. Dread of the woods had long ago been overcome. Nevertheless, three age-long mysteries vexed all minds, and kept alive ancient fears and superstitions: First, what lay behind that seemingly endless wall of mountains that hid the sunrise? Second, why were no human inhabitants visible? Third, was this territory an island, or could it be a dreamland, a delusion? The object in the minds of the leaders of the projected resumption of southward exploration was to find answers to one or all of these really vital questions. Pioneers began to hew their way through the untracked forest, and homeseekers slowly followed their trail broad and beaten, with here and there a lodge where a trapper or a family had paused for time. Season after season came and went, and the trail lengthened out, for nothing, not even an ending, seemed to come of it. Then one day a worn man broke out of the woods, and lo! a vast river filled his vision—the Columbia!

It was not merely the amazing breadth of it, the impressive movement seaward of that unruffled volume of water, the startling thought of a bar laid across the path of further search—these were unconsidered flashes across the eyes and mind of the foremost adventurer standing statuesque beside the noble stream. What really stirred his emotion was the thought that here, at last, the mountains stood apart—that here was rent the gigantic screen that for generations had hid from these wanderers whatever of good or bad lay behind it. So vast a watercourse, he reasoned, must have been gathered from wide and distant sources. Evidently a spacious land, not another ocean, confronted him and this flowing river of sweet water was a road by which it might be reached and its riches learned. Let others cross its current and follow the seashore south as far as they pleased, he and his dugout would voyage upward and eastward into a new world.

So it came about. Little by little, more and more, the people followed their daring leaders up the river. Who could count the years of time expended, who can estimate the facts first learned, the experience and knowledge gained, the growth in intellect and skill required to teach those men and women how to avail themselves of novel resources of food and clothing and adequate shelter.

In time the fierce current of the upper river and massive mountains north stopped advance by canoes. Many pleasing valleys had been left untried, but just here opened a most inviting tributary from the east, the beautiful river now called Clark's Fork of the Columbia. Traced to its source it led the migrants, afloat and ashore, through the varied scenery of this northwestern corner of the Union until they found themselves again confronted by mountains—the long, snow-crowned Bitterroot which stood north-and-south squarely across their progress.

What a trek that was! An unseen,

tenantless, seemingly limitless land. No roads, no guide, no help! Always difficulties and dangers just ahead—risks to be repeated again and again, terrors inspired by superstitious fancy and ghostly loneliness. Great cats, bears, wolves, rattlesnakes surround them, freezing cold, blistering heat. Centuries, perhaps, had passed before this stage of the expedition was ended at the foot of the Rocky Mountains, and a wide space of country with its capability for maintaining human life had been tested.

By this time a line of more or less connected villages and hunting camps marked and kept open a line of communication with the Pacific Coast, and constituted a line of retreat. It needed no military guarding against any humanity save marauders of their own kind, and tribal rivalry and quarrels. But none of those in front, at least, were thinking of a retreat. They were studying the problem that vexed their ancestors, of how to get behind this new mountain-wall and spy out what was there. The thousand-year-old question was not yet completely answered, and an unsatisfied curiosity urged further efforts. In response, an expedition bent on more discovery scrambled through Hellgate Canyon, and found beyond it a break in the range that let them through eastward into a maze of heights and depths, broad peaks and narrow gorges—the heart of the Rocky Mountains. Scouting parties began to get glimpses of lofty peaks ahead whence rivers came. Others followed them, joined from time to time by adventurers who, long before, had turned aside from the Columbia column, and had toiled by boat or afoot up the courses of the Snake, the Salmon and the St. Joseph rivers, which had led them to this lofty meeting-place in the midst of the Rockies. At last the leaders, now gray-headed and wise in the craft of mountaineers, gathered together their nearest companions to climb, at what appeared to be a low place, to the crest of a higher range than had so far been encountered. From the summit of this pass eager eyes beheld streams pouring *away* from their feet—no longer *toward* them, and uniting into a river-way flowing broadly toward the sunrise. First of all men they stood on the watershed of the continent—the Great Divide—and were at the springs of the Missouri-Mississippi rivers.

Picture the mingled pride and wonderment and rejoicing in the hearts of these primitive pioneers! They could see at the base of the range a spacious valley. They would turn their backs to the heights, to the dangers they had endured, would go down to its green expanse, would camp there until those behind them had caught up. But first two things had to be done—messengers must be sent back with the wonderful news, and a huge fire and smoke must be made, to learn by it whether or not the far vista before their eyes held any sort of humankind. No response was visible, and so assured that no enemies awaited them they abandoned any fear about descending the big river as far as it would lead. So they did, and a goodly host followed, and possessed the land in peace.

Let us pause for a moment to suggest what no doubt was happening elsewhere. It may well be believed that during these foregoing years or centuries, part, at least, of the growing mass of inhabitants left on the Pacific Coast had pushed southward, had formed more southern passes across the mountains, had found such rivers as the Platte, the Arkansas and others leading them across the Great Plains; while many, after occupying California, had even followed the Pacific verge into Mexico. Unless, as geologists may show us is the case, a moister climate prevailed then from southern California to Texas, few even of daring scouts would yet have reached the Gulf of Mexico; that discovery more

likely remained for those who ultimately descended the Mississippi. Such episodes and divagations in ethnic dispersal—early movements in the slow spread of a race through thousands of years toward the Atlantic border of their wide domain-to-be—are properly surmised.

Nevertheless, it is my opinion that the main stream of exploratory migration from the Pacific Coast eastward followed in general the course I have sketched. The Columbia-Missouri route has seemed to me to be logical as that by which the unknown interior of the continent would most easily be reached and examined. From the mouth of the Columbia a continuous water-way, navigable for canoes (in which women and children and their meager baggage might be safely transported) led almost to a feasible passage over the supreme mountains; at this point began a noble river, inviting, fairly encouraging, hopeful travel by its smooth current through a smiling terrain. Does a study of the present-day map show any transcontinental route more natural or practicable than this for such emigrants as I have reasonably pictured?

These Neoliths, having crossed the Great Divide and daring to go on, had no alternative but to follow the Missouri —at any rate until their descendants had reached the pleasant prairies and bountiful forests of the Mississippi Valley. Along water-courses, alone, could the aborigines investigate the land—the vacant, guideless land "behind the mountains." By their banks only could they find the edible plants and fruits, the fish and game on which they must depend for food, and for their sole line of retreat if necessary. The rivers were the natural pathways of discovery, and the safe and desirable places for settlement by those who followed the exploration. But these facts imply the possession of boats. And the only boat possible to their powers was the dugout. They had neither materials nor tools for anything else; but with sharpened stones and the keen edges of the shells of river-mussels, tree trunks could be shaped into serviceable boats. To the aborigines, as it has been ever since (before the horse was given to him) his dugout was indispensable in his domestic maintenance; often it was necessary to success in hunting, trading operations or in the constant warring that was the mainstay of tribal coherence; and upon it he expended the highest skill and ingenuity his situation required, together with whatever of art he possessed. Without their dugouts the ancestral Indians might never have been willing to march on until the race had spread from the Columbia to the Hudson.

A STUDY IN THE DEMOGRAPHIC DISTRIBUTION OF CULTURAL ACHIEVEMENT

By Professor CHARLES D. SNYDER
THE JOHNS HOPKINS UNIVERSITY

In the educated world there probably is no one who will deny that the greatest phenomenon of our era is the rise and growth of our western culture and, likewise, no one who does not feel that this culture is a precious thing to be cherished and defended in order that it may maintain its vigor and continue to flourish. That this hope will be realized is not at all certain. We recall that many cultures have risen and flourished in the past only to fall into decay and end in destruction, and that among us to-day there are philosophers who believe that our present culture already is tottering toward a twilight from which there will be no return.

Be that as it may, the present social and political unrest the world over has set many of us to ask anew: What is this thing called western culture, whence did it rise, where is its present center of greatest activity, where are its bounds, who are its enemies and what are the forces that threaten its destruction? Volumes have been written on these themes, but the answers are still incomplete.

Since earliest times man has been aware of group differences among his kind. For centuries he has inquired into the nature of these differences and into their underlying causes, which of them are hereditary and which, if any, are acquired by environmental influences; and of all these, which hinder and which help toward the progress and the happiness of the group in which they are found? Geographical location, prevailing climatic conditions, peculiarities of soil, food and water supplies, endemic diseases, prevailing constitutional habitus and the organs of internal secretion especially dominating the individuals of a people—all these have been the topics of analyses and searching scrutiny.

It goes without saying that the most reliable of all these studies are those that have been carried out with the spirit and the techniques of modern science. Now there are two fundamental factors upon which the scientific approach to any problem is based. The first is the possession of a reliable measuring device, a unit that can be applied for the determination of the quantities of any chosen character or property of the thing to be studied. The second is the choice of a character or property which is really worthwhile measuring. The degree of success attained with the first depends upon the limits of accuracy demanded of (and realized in) the measuring device adopted and the skill and the intelligence of the one making the measurements. The degree of success with the second factor in most cases only becomes apparent long after the work is done; now and then its value becomes apparent at once and the author is acclaimed a genius among his peers.

Perhaps in no field of demography have the difficulties been greater in choosing characteristics worthwhile studying and finding appropriate rods to measure them with than in that branch which undertakes to evaluate the relative spiritual and intellectual, or the cultural, achievements of a people. With the hope that some of the questions men ask about our western culture may be answered by its use, the following description and application of a yardstick for cultural achieve-

ment is offered for consideration. The results of the measurements seem to point to certain conclusions which finally are given brief discussion.

The objects, or characteristics, measured in this study are (a), the number of Nobel Prizes awarded; (b) the number of citations in the International Who's Who for 1937; and (c) the number of record-holders and points won by place winners in the Olympic Games, per each ten-millions of the total population of all the countries represented in each category of achievement. This gives a unit of measure for each category which when multiplied into the population figure of any given country will give the number of points it might have under ideal conditions, in other words, the expectation of merit under ideal conditions in any one of the three fields of cultural achievement here considered. What the actual status of any country happens to be at the present time in any one field then may be found (and this is the yardstick finally to be applied) by dividing the actual number of points standing to the credit of the country by the number of points it should have under ideal conditions. Put in the form of an equation this statement would be,

$$\text{Cultural Status} = \frac{\text{Actual Achievement} \times 100}{\text{Ideal Achievement}}$$

The Demographic Distribution of the Nobel Awards

The five prizes announced for the year 1937 by the committees of the Nobel Foundation[1] bring the number given, since the first in 1901, to a total of 159. One may now assume that, if talent and genius were equally distributed and if the cultivation of the arts and learning (in which the prizes are given) were universal among peoples, then one could say that most probably the Nobel Awards also would be distributed among nations nearly in proportion to their respective population figures. Granting this assumption, one may proceed to estimate the ideal rating for each country by the method described above. This has been done for all those countries which have the distinction of having had one or more of its inhabitants designated as Nobel Laureate. The results of the computation appear in the first three columns of Table 1. As will be seen, the figures representing the actual and the ideal allotments tell quite different stories. Germany, Great Britain, France and the United States of America have received in absolute numbers by far the greater share of the awards. But on the population basis of distribution they have received only one to three times their ideal allotments, whereas Denmark, Norway, Sweden and Switzerland all have been awarded ten times their ideal allotments.

[1] For a brief history of the origin of the Nobel Foundation and a comparative study of the distribution of the prizes see: Harrison Hale, The Scientific Monthly, 40: 157, 1935; *ibid.*, 45: 412, 1937.

The Demographic Distribution of the Citations in The International Who's Who

Recently Captain Frank B. Littell has published an article[2] in which are given the results of his analysis of the numerical representation of the principal nations of the world in the International Who's Who for 1937, "a valuable work of reference containing brief biographical sketches of about 19,000 persons, considered by its authors to be of international prominence."

Here again one may assume that were the people of all lands equal in intelligence, opportunity and training, then the number of biographical sketches in such a work would be pretty nearly in proportion to the population figures of the countries from which they are selected. The actual then would tend to approximate the ideal distribution.

[2] Frank B. Littell, *Science*, 85: 476, 1937.

TABLE 1

DEMOGRAPHIC DISTRIBUTION OF NOBEL PRIZES AND BIOGRAPHICAL SKETCHES IN THE INTERNATIONAL WHO'S WHO

Political groups	Population in ten millions	Distribution of Nobel prizes		Distribution of biog. sketches	
		Actual	Ideal[a]	Actual	Ideal[a]
Germany	6.46	37.0	11.30	8.2	5.40
Great Britain and all Ireland[b]	4.89	26.5	8.55	17.3[c]	4.06
France	4.09	19.5	7.15	9.1	3.30
U. S. of America and Canada[b]	13.24	19.0	23.15	16.2	11.00
Sweden	0.61	10.5	1.07	3.3	0.51
Holland	0.78	6.0	1.36	2.1	0.65
Switzerland	0.39	6.0	0.68	1.6	0.33
Austria	0.67	5.5	1.17	1.6	0.56
Denmark	0.35	5.5	0.61	2.3	0.29
Belgium	0.81	4.5	1.41	1.3	0.68
Italy	4.15	4.5	7.25	3.7	3.44
Norway	0.27	4.5	0.47	1.5	0.23
India	32.56	2.0	56.80	1.3	27.00
Poland	2.72	2.0	4.75	2.1	2.26
Russia and U. S. S. R.	14.70	2.0	25.70	1.5	12.22
Spain	2.28	2.0	3.98	1.2	1.90
Argentina	1.09	1.0	1.91	0.19[c]	0.91
Hungary	0.87	1.0	1.52	2.2	0.73
Totals	**90.93**	**159.0**	**159.0**		
Finland	0.36			1.1	0.30
Australia	0.71			2.1	0.58
Yugoslavia	1.34			1.6	1.13
Czechoslovakia	1.47			1.7	1.22
Japan	7.67			2.6	6.30
Totals	**103.48**			**86.1**	**84.5**

[a] For the method of determining the ideal allotment the reader is referred to the text.

[b] The author has taken the liberty, for the sake of simplification, of putting Great Britain and Ireland into one, and The United States and Canada, into another group. Their individual ratings, when taken separately, are much the same as they stand, as groups.

[c] The author is indebted to Captain Littell, *loc. cit.*, who in a personal communication supplied the data on Ireland and Argentina.

From the data in Captain Littell's article one easily determines the distribution of entries per unit of population and then the ideal allotment for each country. The results appear in the last two columns of Table 1, where again it is seen that for the most part the smaller countries of northern Europe lead the list in realizing on their ideal allotments.

THE DEMOGRAPHIC DISTRIBUTION OF THE WINNERS IN THE MODERN OLYMPIC GAMES

The revival of the Greek Games, putting them on a world-wide basis, no doubt has been helpful in the promotion of international understanding and appreciation. Incidentally the games furnish us with numerical data which can be used in this comparative study of the cultural achievements of peoples.

Such a use of the data has been already begun by the present author[3] with the scores won by the first three place-winners in the 1936 Olympiad. The results in that limited study indicated that the smaller countries of northern Europe, for the most part, did better in realizing on their ideal allotments than did the rest of the world.

Since we have seen above that these same countries of northern Europe indubitably excel in the arts and sciences, the question of their excelling also in athletic prowess becomes of particular importance at this point. For, as is well known, it has long been held by many leaders of educational thought that excellence in artistic and intellectual abilities among a people go hand in hand with excellence in athletic ability. This belief,

[3] Charles D. Snyder, THE SCIENTIFIC MONTHLY, 43: 372, 1936.

however, has been based chiefly upon qualitative evidence. Will a more extensive study of the material on athletic achievements bear out the findings in the study of the more restricted data of the 1936 Olympiad?

To answer this question it was decided to make first a study of the distribution of record-holders in all the Olympiads which are still in force; for it was considered that record-holders in the world of athletics are somewhat analogous to Nobel Laureates in the world of arts and sciences. Second, instead of limiting the study to only the first three place winners, as was done in the earlier work, it was decided to extend it to include all six place-winners in all the events of the 1936 Olympiad. The reasons for this extension are the following: first, all place-winners in all events represent a greater variety of ability and more individuals "of international prominence," more analogous to the variety of abilities represented by the citations in the International Who's Who; second, the last Olympiad is chosen because in that year the variety of sports and the number of nations competing were greater than in any previous Olympiad.

The data on record-holders will be found in the World Almanac, N. Y., 1937, and extend over the six Olympiads held between the years 1912 to 1936 inclusive. By the end of the 1936 games, records had been established in 116 different events, the holders representing some 856 millions of people. The ideal allotment for each 10 millions of population therefore is nearly one and one third

TABLE 2

THE DEMOGRAPHIC DISTRIBUTION OF RECORD-HOLDERS (1912–1936) AND PLACE-WINNERS (1936 ONLY) OF THE OLYMPIC GAMES

Group	Population in ten millions	Record-Holders			Place-Winners		
		Ideal	Actual	Per cent. of ideal realized	Ideal	Actual	Per cent. of ideal realized
Finland	0.36	0.49	9	1837	2.26	17	752
Estonia	0.11	0.15	2	1334	0.69	6	870
New Zealand	0.15	0.20	1	493	0.94	10	1063
Hungary	0.87	1.18	7	593	5.45	44	808
Sweden	0.61	0.83	4	482	3.82	30.5	793
Holland	0.73	1.06	6	566	4.89	24	492
Austria	0.67	0.91	3	330	4.26	26	610
Switzerland	0.39	0.53	1	189	2.45	10.5	429
Germany	6.46	8.77	22	251	40.50	134	331
Norway	2.27	...	..	...	1.69	9	532
Argentina	1.09	1.48	2	135	6.83	16	234
U. S. of America and Canada	13.24	17.98	29	162	83.00	86.5	104
France	4.09	5.55	6	108	25.60	35	137
Italy	4.15	5.62	6	107	26.00	35.5	137
Czechoslovakia	1.47	1.99	2	100	9.22	9	98
Egypt	1.42	1.93	1	52	8.90	7.5	84
Great Britain and all Ireland	4.89	6.62	4	61	30.66[4]	20.5[4]	67
Chile	0.43	0.59	1	107	....	..	..
Belgium	0.81	...	..	...	5.08	5	98
Denmark	0.35	...	..	...	2.19	2	91
Poland	2.72	3.69	1	27	17.05	11	65
Japan	7.67	10.40	7	67	48.10	11	23
Uruguay	0.18	...	..	...	1.13	1	89
Mexico	1.48	...	..	...	9.28	8	86
Turkey	1.37	1.86	1	54	8.60	1	12
Yugoslavia	1.34	...	..	...	8.40	2	24
Rumania	1.90	...	..	...	11.90	1	9
India	32.56	44.10	1	2	204.00	10	5
Totals[5]	91.83	115.93	116		572.89	573	

[4] This figure is based on the scores accredited to Great Britain only, Ireland not having entered the lists in 1936.

[5] Of the total population, as given in Table 2, only 855.9 millions apply in the computations for record-holders, and 918 millions in the computations for place-winners. By theory the totals of ideal and actual allotments should equal each other in each category. The discrepancies between the totals in this respect indicate the degree of accuracy obtaining in the calculations.

TABLE 3

SUMMARY OF RATINGS EXPRESSED AS PER CENT. OF THE IDEAL ALLOTMENT AS REALIZED BY THE ACTUAL ALLOTMENT*

Political groups[f]	Nobel prizes (1901–1937)	Biographical sketches, intern. W. W. (1937)	Olympic games (1912–1936)	Average of all three ratings
Sweden	987	650	638	758
Norway	1048	670	266	636
Switzerland	1138	495	309	625
Denmark	1112	794	46	622
Finland	0	367	1295	554
Holland	443	323	529	432
Austria	470	286	470	409
Estonia	0	10[g]	1102	371
Hungary	66	306	701	358
Great Britain and all Ireland	298	434[h]	64	265
New Zealand	0	5[g]	778	261
Germany	328	152	291	257
France	273	276	123	224
Belgium	318	191	49	190
U. S. of America and Canada	82	147	133	121
Italy	62	107	122	97
Argentina	53	20[h]	185	87
Czechoslovakia	0	139	99	79
Poland	42	93	46	61
Yugoslavia	0	142	12	52
Spain	50	62	0	37
Russia and U. S. S. R.	8	12	0	7
India	4	5	4	4

[f] The order of listing the various nations in Table 3 is determined by the order of excellence, as indicated by the average of all three ratings and as shown in the last column of the table. Of the nations who failed to score in any one of the three categories only those who were honored with the Nobel Prize distinction, or who did exceptionally well in at least one of the other two categories, are included in Table 3.

[g] This figure is based partly on an arbitrary datum, the exact one not being at hand.

[h] See footnote c, Table 1.

* The mean of the per cent. of ideal realized by actual records and by all-events, as given in Table 2, gives the general mean-rating in sports for each country.

record holders. The results of this part of the study are assembled under the caption of "Record-Holders" in Table 2.

The data used as a basis for the study on the distribution of place-winners were published by the Associated Press on August 16, 1936, and represent 28 nations with a total population of nearly 926 millions. A total of 573 points were accredited to those individuals, taking first to sixth places inclusive, and to whom were assigned arbitrarily merits of 10, 5, 4, 3, 2, 1 points, respectively. The results of the computations on these data also appear in Table 2, last three columns. On account of the greater number of entries and points entering into the calculations, the final results differ somewhat from those obtained in the earlier study;[4] nevertheless, the main features of the findings in that study remain unaltered.

We have now compared the actual and ideal distributions of merit in three quite different categories of achievement. The ratios of the two distributions will become much more apparent if we put them in terms of per cent. This has been done for record-holders and place-winners separately for the games, as will be seen in columns 5 and 8 of Table 2. In order to put the merits in games in a single figure the mean of the ratios in these two columns finally is taken for each country. In Table 3 are shown the ratios of actual to ideal allotments of merit in all three categories of achievement. Finally a mean is taken of all three ratios, as shown in the last column of the table. This mean rating in all three categories of achievement establishes an index of the order of excellence in cultural achievement among the various groups. The order of listing them in this table was determined by this order of excellence.

Certain comments on the data used

[4] *Ibid.*

appear to be called for at this point. First, it may be thought by some that the gentlemen sitting on the Nobel Prize Committees, being after all merely human, would not be quite impartial and now and then would give the preference to Scandinavians. Similarly, the editors and publishers of the International Who's Who, being British, and their book being printed in the English language (and therefore destined to be used mostly by English-speaking peoples) the judges inevitably would select a preponderance of names from the lands where the English language prevails.

To offset these misgivings it is only fair to state that, since no specific evidence exists to support them, we must believe that everything has been done to insure a selection of only competent, upright and fearless judges and that those selected have performed their duties to the best of their abilities. It is well known that the judges for the winners of the games were selected from various nations and further, that the automatic devices employed in many of the events were beyond the reach of personal bias and human frailty. But most important of all for the present investigation is the fact that the judges in any one of three fields had nothing whatever to do with the decisions taken by the judges in the other two fields af achievement.[5] It is this last fact that gives our data, when taken all together, a high degree of objectivity and impartiality.

As one scans the results summarized in Table 3, one notes a striking tendency for the order of excellence among the various countries to remain somewhat the same in all three ratings. The outstanding exceptions to this tendency are Finland, Estonia and New Zealand, who, although they have been awarded no Noble Prizes, appear as fifth, eighth and eleventh in the order of averaged ratings. Hungary, who just has been honored with a Nobel Laureate (1937), ranks ninth; Denmark, ranking very low in games, does so well in the other two categories that she still occupies fourth place in the averaged ratings.

On the whole, however, it appears that the general conclusions, drawn in the limited study on the demographic distribution of the first three place-winners in the 1936-Olympiad,[6] also hold in this more extended study. It becomes desirable therefore to restate and to somewhat extend those conclusions.

1. Our yardsticks being European in kind and used to measure occidental rather than oriental ideals of culture, we are not permitted to conclude that the oriental countries standing low in our lists would also therefore stand low in their own kinds of culture measured by their own yardsticks. This study pretends to say nothing in that particular. We can only admire them for having accomplished what they have in our science and games.

2. If figures can add anything to what, because of many other considerations, already has been believed, the present center of occidental cultural achievements lies in western and in northwestern rather than in southwestern Europe.

3. Comparing the ratings in artistic and intellectual with those in the athletic achievements gives definite statistical confirmation to the belief that peoples who excel in the one excel also in the other fields of achievement.

4. It is not the larger but rather the smaller nations of northwestern Europe which excel beyond all others. Mere size of population or spread of empire seems to be no guarantee of the highest mean level of cultural achievement among a people.

[5] The exception to this statement would be the names of Nobel Laureates among the biographical citations. But their number, 159, affect the drift of the 19,000 citations very slightly.

[6] Charles D. Snyder, *loc. cit.*

5. A full explanation of this supremacy of the smaller states will be had only after extensive scientific researches along several lines of which the present author has not the command. But having raised the query, the following brief prolegomenon of the outcome of such researches may be permitted.

At the outset one may say without fear of contradiction that those peoples who satisfy so well our measures of cultural achievement will be found to be made up of less divergent varieties of *homo sapiens* than are those of the less successful groups. The prospective corollary to this proposition doubtless also will be found to hold; namely, that amongst a people where the individuals diverge too greatly in blood and breeding there will be extreme diversity in temperament and conflict of ideals, less balance between dreaming and doing, between debate and decision, more time lost in planning and performing.[7] This state of affairs will lead to constant futility and frustration, so that, even in groups where intelligence is inherently at a high mean level, interest in the social welfare will fail to develop. Amidst their confusion the individuals in such groups will fail either to recognize, or to unite in furthering, the things in life most worthwhile. It is such groups as these who do not know what they want or where they are going.

To begin with then what shall America, what shall all nations of the western world do, who wish to prolong their cultural ideals and national existence? In view of all the foregoing it seems that among the first things to do is to abandon the prevalent timidity and reluctance toward an open discussion of race problems, and of a eugenics which aims not only at the eradication of hereditary (as well as endemic) diseases and low-grade mentalities, but includes also a thorough consideration of hereditary mental attitudes and behavior patterns. Our sex problems have vastly improved since they have been brought out into the open; our race and eugenics problems will likewise benefit by bringing them out into the light. It is superfluous to add that such discussions, to be tolerable and effective, always must be kept on a dispassionate plane.

Since the majority of our people are of northwestern European origins, it is quite reasonable that the control of affairs should finally rest in the hands of leaders selected from such stocks. It is also quite clear, however, that if those, who should be leaders and in control of affairs, become mere onlookers,[8] they will then have only themselves to blame whenever they fall into the hands of minorities.

There is some indication that these minorities are already on the way toward the control of affairs. But if now, before it is too late, our somnolent majority will arouse itself and give full consideration to public affairs it might decide finally to take measures for the maintenance and improvement of the quality of our population by (1) limiting immigration exclusively to selected stock of northwestern European origins, (2) legislating more rigorously against interracial marriages, (3) promoting more diligently enlightened sterilization laws, and (4) adopting policies, which, on the basis of proportional representation, favor individuals and groups who innately sympathize with and give most intelligent support to the ideals of our western culture. Perhaps then all this still may be accomplished in peaceful ways and within the frame of a democracy.

Perhaps then even America will know finally what she wants and where she is going.

[7] For further discussion of this, see Madison Grant, "The Conquest of a Continent," N. Y., 1934, Chapter 18.

[8] John R. Tunis, *Atlantic Monthly*, August, 1937.

THE THEORY OF THE GENE[1]

By Professor RICHARD GOLDSCHMIDT
UNIVERSITY OF CALIFORNIA

MORE than thirty years of experimental research in genetics have established the fact—as it seems, beyond discussion—that the fundamental unit of heredity is the gene. Some biologists call the gene even the unit of life, meaning that the existence of the living world is unimaginable without the existence of the gene. A lecture on the theory of the gene is therefore expected to discuss the facts which led to the conception of the gene as the hereditary unit and, maybe, of possible objections to these facts. The discussion might be extended to the possibilities of understanding the nature of the gene, and in this connection also the problems concerning the action of the gene in controlling development might be included. But the title of this lecture is meant in a different sense. What we intend to discuss is not the existing classic theory of the gene, but the reasons why we believe that this classic theory is no longer tenable and has to be superseded by something else.

There have always been biologists who were sceptical regarding the classic theory of the gene as a hereditary unit. Johannsen, himself, who coined the term—though the actual conception goes back to Roux, Weismann and De Vries—did not like to think of the gene as of an actually existing unit. But he was also opposed to the chromosome theory of heredity. Actually, his scepticism was completely sterile and therefore not justified in his time, when every single fact which had come to light forced the theory of the gene as an actually existing unit upon the minds of geneticists. There were also other biologists who opposed the theory of hereditary units on general grounds. They had to disregard all known facts of genetics in order to prove their point and were therefore in the wrong even if it should turn out now that their sterile scepticism in the face of overwhelming facts had happened to put them after all on the right side.

[1] Lecture delivered before the University of California chapter of Sigma Xi, November, 1937.

Any text-book of genetics will convey the information upon which the theory of the gene as a hereditary unit is based. The elementary facts of Mendelian heredity show that the things which control hereditary traits are distributed according to chance and that they may be recombined according to chance without ever losing their identity. When it became known that the behavior of the chromosomes in the sex-cells paralleled exactly the distribution of hereditary traits among the progeny, these traits appeared to be based upon something located in the chromosomes. Then came the discovery that more such unit traits could be traced in one species than the number of chromosomes would permit. This meant that more than one unit character is located in a chromosome and that such a group of characters is expected to be linked in heredity. The next step was the discovery that this linkage could be broken by crossing over and that this exchange between homologous chromosomes could occur at each single locus, *i.e.*, for every single representative of a unit character in the chromosome, called a gene. This meant that small units, responsible for the individual linked traits, must be contained within the chromosome and that these must have a real existence, as they may be shuffled around. Then the law was found that the amount of cross-over is a function of the distance of these units within the chromosome, which in its turn required a linear arrangement of the units. It followed the

discovery that the same number of linkage groups is found as the haploid number of chromosomes. Then came the discoveries of exchanges of parts of chromosomes (translocations), deletions of parts (deficiencies), inversions of parts; and in every case the actually found consequences were those which could be predicted on the basis of the theory of the gene, *i.e.*, of the existence of units arranged in an orderly bead-like seriation along the chromosome. All these facts could be brought to light because one of the fundamental properties of the supposed units, the genes, turned out to be their ability to change by the process of mutation. This change in the gene leads to a mutant character which may be followed up in crossing experiments, again behaving as a constant unit. It is clear that actually only the mutated gene is accessible to experimentation. But as the hereditary behavior of each mutant gene requires the existence of something, called the wild type allele, at the same point of the chromosome in the normal (wild) stock, mutation must be supposed to have changed a wild type gene into the mutant gene. It further became known that one and the same gene may mutate into a series of alleles (multiple alleles) which again requires the existence of a unit, the gene, capable of a series of changes into other (and again stable) units at the same point of the chromosome. The last touch was given to the classic theory of the gene when it was found that gene mutations may be induced experimentally by x-rays and other agencies and, further, that practically all the details of gene arrangement, as derived from genetic experimentation, could be confirmed cytologically in the giant salivary chromosomes of Drosophila.

This immense body of evidence then showed that units called genes exist at definite points of the chromosome, units which are stable, which can be shifted here and there without losing their identity, which exercise a constant effect upon the developing organism, and which may change spontaneously or under experimental conditions into another stable unit by mutation.

Many hypotheses were evolved regarding the nature of the gene. Though some cautious biologists spoke only of a locus in the chromosome, the majority formed some kind of an idea regarding the nature of the gene, and a great many geneticists have spoken their mind on this point. We do not intend to review these ideas, which in each instance were prompted mostly by such facts as were foremost in the minds of the respective authors.[2] In a general way we may state that the gene was assumed to be a single molecule or a group of molecules of some active substance, probably an autocatalyst. Mutation was assumed to mean either a change in the number of molecules characteristic for the gene, or a change in one side-chain, or a change to a stereoisomere or even a larger change of molecular order. When it became known in recent times that the fibers are composed of micellar compounds of long chain-molecules, a similar constitution was also ascribed to the gene.

The first difficulty arose for the classic conception when the so-called position effect was discovered. Sturtevant found that two Bar eye genes in Drosophila, located in the same chromosome as a result of unequal crossing over, have a different effect from the two B-genes located opposite each other in two homologous chromosomes. He called this a position effect, which would mean that the position of a gene influences its action. This could imply that not only the locus or gene but also the whole chromosome means something for the action of what is called a gene. Recently many

[2] A full review will be found in a book now in press. ("Physiological Genetics," McGraw-Hill Co., New York.)

effects were found which were described under the same name of position effect, though they are absolutely different from the original Bar case. The x-ray technique led to the production of innumerable translocations within the same or between different chromosomes, inversions and similar rearrangements of chromatin material. In many cases they were combined with what appeared to be a mutation at the breaking point or nearby. As such a mutation at the break became less probable with the increase in the number of cases found, the effect was considered by many geneticists to be a position effect. This means that a gene which is put in a new neighborhood, as is the case with a gene adjacent to a break, has another effect than in its normal surroundings, an effect which resembles the effect of a gene mutation, though the gene has not changed at all. If the rearrangement returns to normal, the effect also disappears. To explain this effect within the theory of the gene it was assumed that a part of the action of the gene takes place near its locus. Here, then, the products of its action are most concentrated. If the gene is transferred to another locus these products interact first with something different, namely, the products of the now neighboring genes, and therefore produce a different effect.

It is obvious that this theory of the position effect could save the conception of the gene up to this point. Further facts, however, make it rather difficult. One of the important results of the x-ray experiments was that both gene mutations and chromosome rearrangements were produced in direct proportion to the rate of ionization and independent of wave-length. It was further found that the phenotypes of the gene mutations and of the so-called position effects covered the same characters. But the study of experimental chromatin rearrangements brought another important fact to light. If at (or near) a definite locus of a chromosome anything happens in the way of a rearrangement, an inversion, an insertion of a piece from somewhere else or a deletion, a phenotypic effect may be produced which is identical with the phenotype of the gene mutations, typical for this locus. Anything happening at the Bar-locus may produce a Bar effect. This change then acts in the language of classic genetics like a multiple allele of the respective mutant. It is obvious that it is very difficult in such a case to distinguish between a position effect and a gene mutation. The only difference is that in one case we know that the phenotypic effect is produced by a rearrangement of chromosome material; in the other case we do not know this yet. The suspicion is strong that the gene mutation at the locus in question is also the result of a rearrangement, maybe one which is difficult to make visible cytologically on account of its involving only a very small chromosome section.

There are quite a number of facts existing which lead our thoughts in the same direction.[3] The suspicion would become a certainty, however, if it could be shown that ordinary and typical so-called gene mutations are actually the results of a rearrangement. This now has been demonstrated with certainty for quite a number of standard genes.

The process of spontaneous mutation, as usually occurring, involves the sudden appearance of a single or of a few mutated individuals. We have observed now a series of cases—as it seems, very rare cases—in which something occurs which looks like a strange type of mass-mutation. (One such case has also been found by Plough and Holthausen and actually been termed mass-mutation.) In these cases a whole brood of Drosophila had suddenly changed into a series of mutational types. Thus simultaneously a series of "mutants" appeared in numerous individuals, and some of them turned

[3] See footnote 1.

out to be identical with well-known gene mutations. In this case, however, it could be proven that chromatin rearrangements had taken place spontaneously, which at once produced all these types. Already three major and three minor individual instances have been observed since 1929, and there were produced a large number of "mutants," among them such standard mutants as black, purple, ebony, dumpy, plexus, rudimentary. If this can happen there is no reason to doubt that in due time all other mutants will appear in the same way. To save the gene concept one might still say that all these were cases of position effects and that the original gene mutants were something else. I do not doubt that the not yet completed detailed analysis of these cases will enforce the abandonment of such a last desperate stand. The conclusion, then, is that gene mutation and position effect are one and the same thing. This means that no genes are existing but only points, loci, in a chromosome which have to be arranged in a proper order or pattern to control normal development. Any change in this order may change some detail of development, and this is what we call a mutation. We might of course call a change of arrangement at a locus, a gene. But then there are no genes in the normal chromosome, and the mutant gene has no wild type allele, as the whole wild type chromosome is the allele for all mutant genes in the chromosome. Better, then, give up the conception of the gene except for simple descriptive purposes.

The situation is now this: The whole chromosome is the unit controlling normal development. But in this unit the different points must have a definite order, which is of so complicated a type that most changes of the proper order are either lethal or change the activity of the chromosome in development thus that a different phenotype results, the mutant type. This change of activity with the result of mutant development is, generally speaking, not so mysterious as it may appear at first. We have shown that in Drosophila the phenotypic likeness of the majority of known mutant types may be produced at will by such simple agencies as temperature shocks applied at definite stages of development. These so-called phenocopies then demonstrate that an external and simple quantitative agency can change developmental processes in the same way as an upsetting of the order within the chromosome does. This again suggests that changes of order, if viable at all, result in relative simple deviations from the normal course of events, deviations which probably may be reduced to a large extent to changes in velocities of some integral processes.

If such is the case, we shall have to ask ourselves whether we are facing here in the set pattern of the chromosome something of the order of the mystic "wholeness" which has become so fashionable in the biological literature of certain countries, or whether a chemical model might be imagined which could account for such facts. Actually I believe that such a model is available and that it leads to such interesting comparisons that I may be excused for indulging in a little speculation along this line.

There has already been proposed such a model by Miss Wrinch, which had quite a success with some geneticists. This model, however, still assumes the existence of genes. The chromosome is conceived as a micellar combination of long chains made up of different polypeptids and held together by nuclear acids. The bonds between the different polypeptids are breakage points and anything between two bonds would constitute a gene.

A better, though nearly related model, fulfilling all the requirements made by the facts of genetic experimentation, may be derived from recent work of Bergmann and colleagues upon the constitution of the protein molecule. The facts

which the geneticist wants to be represented in the model are: (a) The ability of the chromosome to reproduce its own image by division or by recreation of its likeness. (b) The point to point identity of two partner-chromosomes as expressed by point to point attraction all along its length. (c) The orderly diversity along the length of the structure of a sufficient complexity to make a change in order in a majority of cases consequential (*i.e.*, change of order equal to mutation). Bergmann starts from certain facts upon which he builds a chemical hypothesis, and both facts as well as hypothesis appear very helpful for our present purposes. The protein molecule is known to consist of a chain of amino acid residues linked by peptide bonds. According to Bergmann these residues are arranged in a simple order. Each amino acid has its own rhythm different from that of the others, and the superposition of all these rhythms produces the pattern of the molecule. The rhythm itself, meaning that one type of residue appears always separated by a definite number of others in the chain, follows a simple arithmetical rule. Thus silk fibroine which contains glycine, alanine and tyrosine residues shows an arrangement of these in the rhythm:

G-A-G-X-G-A-G-X-G-A-G-T-G-A-G-
X-G-A-G-X-G-A-G-X-G-A-G-T-G
(G-G = 2 A-A = 4 T-T = 16)

The total number of members of a chain is 288 or a multiple thereof. To organize such a molecule, a chemical organizer is needed of immense specificity. According to Bergmann, the only known substances with the necessary properties are the intracellular proteinases, which both hydrolyze and synthesize the protein molecule. At this point Bergmann pronounces the hypothesis that the proteinases are themselves proteins. "If the proteinases themselves are proteins and at the same time have the ability to synthesize other individual proteins then there must exist proteinases which have the ability to synthesize replicas of their own structural pattern and therefore are able to multiply in suitable surroundings."

It is astounding to see how these chemical facts and hypotheses fit the requirements for a chemical theory of heredity. Let us assume that the individual chromosome actually is a single immense chain molecule and a proteinase. (This means the essential part of the chromosome—the so-called gene string—to which is added nucleic acid, which makes in some way the stability of the long chain possible. All modern hypotheses regarding chromosome structure have reckoned with these two constituents.)[4] This proteinase then has different properties according to its special surroundings. Either it may produce its own replica, which amounts to a division of the chromosome or it may synthesize other proteins from the parts present or it may hydrolyze proteins. The latter two activities would constitute what is usually conceived as being the function of the gene. The immense specificity of this proteinase is based upon its typical structure. This, however, represents a most complicated though regular pattern, composed of the superimposed rhythms of the different amino-acid residues. This again means that any breakage or rearrangement in the chain leads to a destruction or impairing of the specificity and therefore to other reaction products, which have to be assumed to control the phenotypic changes. Thus it seems that the latest developments of genetics and of protein chemistry permit the statement of a reasonable hypothesis regarding the chromosome, which could easily be elaborated much further.

If the views expressed here should turn out to be correct, a number of far-reaching consequences would become visible.

[4] See footnote 1.

If the chromosome and not the gene is the actually decisive unit, we shall have to revise quite a number of our ideas concerning evolution. In addition we shall have to look at such genetic facts which deal with whole chromosomes from a new angle. For example, in plants trisomics (one chromosome present in triplicate instead of duplicate) have been known to be different from normal diploids and the types produced by the addition of an extra chromosome are among themselves different according to the individual chromosome involved. The fact has been explained on the basis of the theory of genic balance, which is disturbed by an extra chromosome in favor of the genes contained therein. But we know that actually "genes" controlling a definite character (*e.g.*, eye color in Drosophila) are distributed over all chromosomes. The typical differences between different trisomics (different in regard to the chromosome involved) are therefore rather surprising. Still less understood is the fact that different trisomics (according to Blakeslee and Goodspeed-Avery) are distinguished not by different combinations of traits but by the complete habitus of the plant. If no genic balance is involved but the action of a chromosome as unit the facts appear in a different light and their importance increases. Only in passing we might mention that we may possibly also have to change considerably our views regarding sex chromosomes and sex genes.

May I finally point out that the geneticist may furnish the protein-chemist with an interesting fact. In the chromosome there exists a mutual attraction between two and only two identical chains point by point, link by link. The protein-chemist obviously has difficulties in understanding the series of reactions by which a proteinase organizes the pattern of a protein molecule or of its own replica. From the fact just mentioned some information might be derived which would lead to a physical attack upon the problem of organizing or patterning a chain-molecule.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]
WASHINGTON, D. C.

M-RAYS' EXISTENCE DOUBTED

"Not proven" is the Scotch verdict returned by two critical biophysicists after a careful investigation of the disputed phenomenon of mitogenetic radiation, or M-rays. The two men, Drs. Alexander Hollaender and Walder D. Claus, pursued their researches at the University of Wisconsin for the National Research Council. The council recently published their report.

Mitogenetic radiation, known also by the convenient nickname of M-rays, was first reported by a Russian, A. Gurwitsch, some years ago. He stated that tissues of rapidly dividing cells, such as root tips, emanated some kind of short-wave radiation, of very low intensity, that nevertheless was capable of stimulating other cells to divide also.

Many other investigators, using many methods, have followed the work of Gurwitsch. A favorite set-up is an onion root tip as source of the rays and a small mass of yeast cells as "biological detector."

Although many efforts have been made to detect the rays with mechanical apparatus, such as modifications of the Geiger counter used in cosmic ray work, none of them has ever been successful. This, however, does not necessarily militate against the validity of the observations, for living organisms are still far better detectors of many natural forces than any mechanism yet devised.

However, when Drs. Hollaender and Claus repeated the work very critically, using both physical apparatus and biological detectors and checking carefully every step in every experiment, they were unable to obtain any evidence satisfactory to themselves of the existence of mitogenetic radiation. They therefore rest their case with a negative verdict, at the same time stating their willingness to reopen it again if supporters of the M-ray hypothesis come forward with positive evidence produced under really rigorous experimental conditions.

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

VITAL CHEMICALS

Certain chemicals, among them phosphorus and the sodium of common table salt, are vitally needed by the body. Medical scientists have known this for some time from observing the disastrous results that occur when these chemicals are lacking from the diet which is the normal source of supply.

Knowledge of the part these chemicals play in the body—phosphorus as an aid in bone-building, for example—has been gained by examining and analyzing the bones and other body tissues after death, and correlating these observations of the amounts of each chemical in the various tissues with the observations of what happens when an animal is deprived of them.

Now scientists can get much more direct information about what happens to some of these chemicals in the body and what they do there. The chemicals are made to put themselves on the spot and show where they are from the moment of entering the body until they leave it. This is done by adding to the substance under observation a bit of the same material, made artificially radioactive. This bit of material can be detected by the powerful rays it is constantly giving off, just as radium itself can be detected by its rays.

There is no danger from the artificial radioactive substances because they lose their radioactivity in a short time—fourteen hours in the case of radiosodium. In fact, this makes it necessary for very fast team work between the physicists who endow sodium or phosphorus with radioactivity and the medical scientists who use it for physiological studies.

Besides observing how substances such as phosphorus and sodium are used by the body, scientists, by tagging them with radioactive material, can learn how they are changed by disease and can check on radioactive treatment of cancer. Radioactive substances for such studies are now being produced in quantities by the cyclotron at the University of California under the direction of Professor E. O. Lawrence.

COAL IS STILL POWER KING

Coal is still power king and is the energy source upon which the future must rely, despite the relative decrease in its use that has occurred in recent years.

Natural supplies of oil and gas and the electricity that comes from water power will not in future years supply our needs. Technical experts look forward to the day when coal will supply us not only with the bulk of our power from central stations but with superior synthetic fuels, such as gas for heating, liquid fuels for internal combustion engines, and smokeless solid fuel for home heating.

Inevitably an end to flush production of petroleum and natural gas will arrive, not suddenly but gradually and steadily, a survey made by the Ontario Research Foundation shows. This will be due both to enforced conservation measures and to changes in the economics of the industry. Synthetic manufacture of oil and gas from coal will become more economically justified with increased cost of natural oil and gas. Relatively less coal will be burned raw.

Even now figures show that almost a third of the bituminous coal produced in America is processed. A single coking plant near Pittsburgh consumed one per cent. of all the coal mined in the whole world. Processing of coal, taking out the rich chemicals that dye our textiles, make our medicines, supply raw materials for industries, creating gaseous and liquid fuels and leaving coke for metallurgical and other uses, will inevitably become one of the largest of our industries.

Public health factors and the economic losses due to smoke that blights many of our large cities will demand that smokeless fuels and fuels processed and purified for special purposes be used practically exclusively. Burning untreated coal may be considered almost a crime. We derive our power from the fossil sunshine of past geologic eras. We are living on the energy savings of the past. We are, alas, scattering our power resources over the face of the earth in fine dust and degraded energy.

HELIUM, SUN ELEMENT, SOON TO HOLD AIRSHIP ALOFT AGAIN

Soon the compressors at Amarillo will be whirling full speed handling millions of cubic feet of nautral gas in order that helium, the sun element, may again hold aloft an airship.

Twenty years ago with great secrecy American engineers and chemists converted helium from a "rare" gas, commanding $2,000 a cubic foot, into a noninflammable competitor to hydrogen as a lifting gas for balloons and airships. When the armistice was signed thousands of cubic feet of helium in cylinders were on a New Orleans wharf ready to be shipped for use in the world war.

Now the Germans, the disaster of the hydrogen-filled *Hindenburg* fresh in their memories, are about to use some 18,000,000 cubic feet of helium for the initial inflation and replenishment during flights that the new Zeppelin *LZ–130*

will make this summer between Europe and the United States. America has a monopoly on commercial supplies of helium, and Congress after the burning of the *Hindenburg* enacted a law allowing its sale for restricted commercial, research and medical uses.

The extraction of the 1.8 per cent. helium in the natural gas from the Cliffside field in the Texas Panhandle is the task of the U. S. Bureau of Mines. Underground in the government-controlled gas field that supplies the Amarillo plant there is an estimated reserve of 1,800,000,000 cubic feet of helium, enough for years to come. Some smaller gas fields in Utah that are much richer in percentage of helium have also been set aside and steps are being taken to purchase helium properties near Dexter, Kansas, and Thatcher, Colorado.

Sufferers from asthma and "sandhogs" and deep sea divers who work under pressure will benefit from the availability of helium. The gas is used in preventing the "bends" when under-pressure workers are decompressed. And helium is proving useful in treatment of respiratory diseases.

SOUND-ABSORBING LAYERS OF LITTLE USE IN MOTOR CARS

The amazing sound-absorbing materials which still the clatter and noise of busy restaurants and cafeterias seem to the layman to be the ideal for the job of quieting the interior of his motor car. The reasoning for this assumption is straightforward enough on the thought that what is good for noise reduction in one case is equally good for another.

Acoustical engineers, whose job it is to study sound, wish the problem really were as simple as this. The truth of the matter is that sound-absorbing materials which work so well for stilling noise in a cafeteria or improving remarkably the acoustics of an auditorium are of almost negligible value as a lining for the interior of a motor car.

The reason is that sound-absorbing materials are practically "transparent" to sound. Because they permit sounds to penetrate within them they are highly valuable for noise problems due to sound reflections. This is the type of problem which appears in auditoriums where troubles are most often caused by excessive reverberation or multiple reflections of sound so that one hears the sound prolonged to a confusingly lengthy time.

But the very transparency of sound-absorbing materials makes them ineffective for silencing noises originating outside the chamber they are designed to shield; noises from the engine, from vibration in the frame and other places. To stop such sounds dense, hard materials like glass or steel are best because they reflect the noises more toward the outside. The use of these dense materials, however, permits ready entrance into a motor car's interior of actual mechanical vibrations which can, in turn, create sounds inside. Elastic materials like rubber are employed between separate sections of the body to damp out these mechanical vibrations before they become sources of sound within the car.

NEW SWEDISH PROCESS FREEZES SALT FROM OCEAN

Salt seems so commonplace in America to-day that it is hard to realize that it was one of the economic commodities which played a great rôle in fashioning the ancient highways of commerce. One of Italy's oldest roads is the Via Salaria that linked the salt pans of Ostia with the Sabine country. Even to-day the main part of caravan commerce across the Sahara Desert consists of salt, for in the interior of Africa salt still ranks as precious and retains something of its status of the past when it was used as money.

But one need not go into darkest Africa to find a region where salt is a crucial problem for a nation. There is Sweden. Sweden has no salt and no fuel; the latter

being significant because one can evaporate salt water if an abundance of fuel is at hand for a fire. Yet Sweden has an abundance of hydroelectric power and thereby has one key with which to unlock the doorway which guards the salty waters of its majestic fiords.

Sweden is now building an experimental factory on Gullmar Fiord in which salt will be produced by freezing. The U. S. Bureau of Mines reports that Gullmar Fiord contains a very high percentage of salt in its waters. At the experimental plant this water will be frozen by the abundant electric power in mechanical freezing units and a very concentrated salt solution thus obtained. This salty brine is then evaporated by heat, but much of the work of getting the final salt crystals has already been done by the freezing. Thus the scarcity of fuel can be overcome, in large measure, by Sweden's tumbling torrents.

ELECTRICITY AND SKELETONS PROLONG CIVILIZATION'S LIFE

Electricity, working on myriads of skeletons from which life departed millions of years ago, will do much to prolong the life of our own civilization. This apparent paradox, which modern science makes real and even commonplace, is explained and emphasized in the new annual report of the Tennessee Valley Authority. New processes of making better phosphate fertilizers in electric furnaces promise to revolutionize the whole fertilizer industry, and with it agriculture, and with agriculture the tenure of civilization itself.

But where do the skeletons come in? In the phosphate rock. Indeed, to a very large extent, they *are* the phosphate rock —it consists of thick deposits of ancient animal skeletons, ranging from fish down to one-celled organisms, left on the bottoms of ancient seas and since pressed and hardened into stone.

The electric-furnace method of preparing phosphate fertilizer does two things: it makes a much more concentrated, effective fertilizer, that costs less in freight from furnace to field; and it makes possible the economic utilization of lower grades of rock than can be worked by present methods, and that without the use of sulfur now required. Even without waiting for the full developing of the electric-furnace method, TVA phosphates have been put into wide use in many places throughout the valley and in several states outside. Distributed with the strict understanding that they are for use only in soil-restoring plantings, TVA phosphates are establishing pastures, checking erosion and capturing six pounds of nitrogen from the air for every pound of phosphorus, through the agency of plants which they fertilize.

Important for the power and navigation use of the river itself is the development of the valley phosphorus program. For if the great reservoirs behind the dams fill up with erosional silt, the whole vast project comes to naught. Insuring that water for these reservoirs comes from grass-floored valleys, not from crumbling gulleys, is not the least of the tasks of phosphates from the furnaces of the TVA.

THE FORMATION OF YELLOWSTONE CANYON

Millions of years ago, a river in the Northwest took the "hard way." As a result, to-day millions of tourists stand in awe, every summer, gazing into the pastel-tinted Grand Canyon of the Yellowstone.

The tale is told by Professor Arthur David Howard, of New York University, in a report to the Geological Society of America. The Yellowstone River has its source in Lake Yellowstone, which lies right up against the Continental Divide, in the great national park of the same name. The river flows first north, then west, cutting deeply through a couple of mountain ranges, finally joining the Missouri at Ft. Union on the eastern

boundary of Montana. Thence its waters continue their long journey toward the Gulf of Mexico.

At the southern end of Yellowstone Lake, the Continental Divide is not all the place of rocky steepness its name might suggest. There is a very wide pass —so wide and flat, indeed, that its floor is a wet meadow most of the spring and summer. On the other side are streams that eventually reach the Pacific, by a much easier route. Why did the river take the more difficult way?

The paradox is only apparent. Yellowstone waters also flow downhill; and downhill, in the early days of the river, was toward the north. The mountains were still a-making, and as they rose the river cut through them and kept a way open. During the Pleistocene Ice Age, glaciers apparently blocked the northern drainage one or more times, and the lake did then overflow the divide and drain toward the Pacific. But when the age-long ice-jam went out, it resumed its northerly flow.

The river has not kept in the same channel all the time, Professor Howard found. He confirmed the observations of other geologists who studied the terrain before him, that there is an old channel of pre-Ice Age date, high on the uplands above the present gorge bottom. He also describes a second channel, proved to be of Ice-Age date by sediments of that age found in it. The river now occupies a third, comparatively new channel.

SOUTHERN EUROPE'S EROSION

The goat, irrepressible, omnivorous, cropping every living shoot level with the bare soil, was pointed out as the cause of the age-old soil-erosion problem of southern Italy, Greece and other Mediterranean countries, in a Royal Institution lecture delivered in London by Sir Daniel Hall, director of the John Innes Horticultural Institution.

First, the forests were stripped from the hills, and no provision made for their replacement. Then came the pressure to extend the limits of grazing. "Grazing is all very well if regulated," said Sir Daniel, "but unfortunately in these Mediterranean countries goats are among the chief grazing animals."

"It is no accident that old tradition has represented the Evil One with the hooves of a goat, for of all animals the goat plays the devil with land. Hungry goats will eat anything that grows; they destroy every seedling tree as fast as it gets its head up; they complete and extend the destruction the wood-cutters have begun."

Then comes the cycle all too familiar to Americans who have seen over-grazed land: the animals' sharp hooves cut the surface of the soil; they beat down hard little paths, invitations to runnels of water when the rains come. These become first little gullies, then great gashes, and presently the slope is slashed into badlands. "Such has been the history of much of the fairest land on the seaboard of the Levant," said Sir Daniel. "On the heights bare rock where once forest and meadow flourished, rivers that are torrents in winter and dry in summer, old seaports no longer accessible."

"The destruction of the forest was thus a major factor in the decay of Greece and Rome itself; it means in the first place the loss of farming land and of the agricultural population which formed the backbone of the early armies of the republic."

THE ROLE OF GLANDS IN MENTAL DISEASE

One of the most puzzling problems faced by the scientist exploring man's mind is the rôle played by the powerful glands of the human body. A matter of demonstrated fact is the knowledge that these glands serve as chemical factories, pouring out potent substances capable of changing the whole behavior of the individual. Presence or lack of a glandular chemical may make a person

energetic or lazy, submissive or rebellious, mentally alert or stupid.

That the endocrine glands occupy a place of power in determining the mental soundness or illness of the individual has long been suspected by physicians and psychologists. Glandular disorders have been noted in the mentally ill and to some this has meant that the glands could be blamed for the mental illness. Others, reversing the relationship, see the emotional strains of mental disease as effective in throwing the endocrine system out of balance.

Actually, medical science to-day has no crucial evidence of any cause and effect relationship between the glands of internal secretion and mental disease or mental deficiency, Dr. Hugh T. Carmichael, psychiatrist of the University of Chicago Medical School, told his colleagues at the recent meeting of the American Association for the Advancement of Science.

A recent survey showed that of a group of about 300 mental patients selected for endocrine diagnosis and treatment more than a third were so improved that they were able to leave the institution. Further analysis showed that only 17 per cent. of those selected for endocrine diagnosis actually had anything wrong with their glands, and less than half of these had adequate gland treatment. In addition many of those "cured" had had a type of mental disease that often disappears spontaneously. Mental disease and mental deficiencies are common. So also are glandular imbalances. That they are often found in the same individual could be simply a matter of chance. The rôle of the endocrines is still an unsolved problem and presents a fruitful field for future research.

LENGTH OF LIFE AND FOOD SELECTION

The old adage, man is what he eats, unlike some of the old-time sayings, gets more and more confirmation from scientific research. Length of life as well as health is now said to depend to a large degree on a wise selection of food for the daily diet. This means eating foods every day that contain each of the three great classes, proteins, carbohydrates and fats, and that also contain the important minerals and the popular as well as essential vitamins. Most of us have learned by now that in order to keep well meat and potatoes, bread and butter, eggs, cereal and sugar and cream must be augmented by raw and cooked vegetables and fruits and by milk.

Now the food scientists tell us that eating just enough of these to keep well is only the beginning. Keeping well usually means avoiding ill health. But by eating extra amounts of the foods that contain vitamins and minerals—the protective foods, so-called because they protect against sickness—one can not only avoid sickness but increase vitality and length of life.

In the case of riboflavin, which used to be called vitamin G, scientists at Columbia University have found that an almost infinitesimal amount in the daily diet will keep animals normally healthy and able to reproduce generation after generation. But by increasing the amount of this substance in the diet, the animal's nutritional well-being can be increased to three times the minimum adequate level. The offspring of these animals also benefit to the extent of being four, seven and even ten times as healthy as the minimum standard of health demands.

While the studies were made on laboratory animals, the results may be applied to human animals. The differences in the relative proportions we choose of the staple foods in our daily diets may make enough difference in the body's internal environment to make us immeasurably healthier throughout a lifetime.

POPULATION TO DECLINE DESPITE INCREASES IN PAST

Man power—or brain power—is the

most valuable resource of the world, for out of it arises civilization and culture.

There has been a certain complacency about the renewal of our human resources. The population of the world trebled in the last 160 years. The white races increased from 150,000,000 people in 1780 to 635,000,000 in 1930. That would seem to justify the idea that there is no need for worry about the natural increase in population.

To-day it is possible for the first time to inventory, with some scientific accuracy, man power not only by quantity but by quality as well. Frederick Osborn, of New York City, who has collaborated with Dr. Frank Lorimer on population studies, reported recently to the American Association for the Advancement of Science that the old process of population growth is coming to a sudden stop among peoples living in cities. A period of decline has arrived in most countries of Western Europe.

By using crude birth and death rates, experts as recently as a decade ago found the population appeared to be rapidly increasing. But when the age grouping of the population and other factors were considered, it was found that true rates for 1930 were 16.9 births per 1,000 and 16.3 deaths per 1,000, contrasted with crude rates of 18.7 and 10.8.

The slight excess in the rate of intrinsic reproduction in 1930 above that needed for replacement has been whittled away since that time, Mr. Osborn finds. There is no doubt that the country is at present declining in numbers in the true or intrinsic sense. The best guess of the population students is that the fall in birth rate will continue, and that the gross population will be something less than 150,000,000 in 1970, declining thereafter.

PRESERVATION OF NAVAJO LORE

Science must work fast to get information now stored in Navajo Indian minds, warns Francis H. Elmore, of the State Museum at Santa Fe, who has been querying these Indians on use of various plants.

The Navajo had ideas for using at least 500 plants growing in their Southwestern country. The great outdoors was a shopping center where a Navajo could go for basket materials, for food, drinks, medicines, dyes to brighten a garment, games for the children.

But that's changed. With government aid, and with ways of earning money from blankets, silverware and sheep brought to Navajo attention, these Indians have taken much of their "trade" away from the old plant stores. Conservatives still prefer some of the foods eaten by their forefathers. But Mr. Elmore explains that a Navajo has learned that he can buy food almost as cheaply as he can gather it, and with half the trouble.

Consequently, a young Navajo is little better at describing ancestral customs than a young New Englander might be at telling you how his great-great-grandmother made soap. Some older Indians still have valuable information, but Mr. Elmore warns that "in a few years the Navajo will probably have forgotten how many of the plants were used."

Early Navajo lived chiefly on corn, as these Indians still do, he explains. But whenever war or roving interfered with farming, resourceful Indians could live on seed, roots, stems, and leaves, sustaining themselves even on long journeys. The daring of the traditional first-man-who-ate-an-oyster was matched by more than one Navajo who tasted some scrubby fruit to try its food value.

Study of Navajo ways may yield useful information. Mr. Elmore foresees. The pinon nut, Southwestern Indian fare, has become a commercial article for the white man's market, and other Navajo plants may prove useful to us, as to them.

THE FISH IN THE IRON MASK

AND OTHER FISHES WITH IRON RINGS AROUND THEIR NECKS

By Dr. E. W. GUDGER

ASSOCIATE CURATOR OF FISHES, AMERICAN MUSEUM OF NATURAL HISTORY

In another article[1] I have discoursed of mackerel, bluefish, haddock, gar and needle-fishes wearing rubber bands about their bodies; of a swordfish and a sturgeon each with such a band around its snout; of four dogfish each with a rubber band around its body in the neck region (if such may be attributed to a fish); and finally of a fair-sized shark carrying about with him an automobile casing. In this article, however, I purpose setting out some extraordinary instances of fishes wearing adornments of iron and shell.

The Fish with the Iron Mask

In August, 1931, the picture reproduced herein as Fig. 1 was published in *Field and Stream*. It shows a 15-pound codfish with its head confined in a syrup can. The fish was discovered in water about six feet deep at Point Fosdick ferry landing on Puget Sound, Washington. It was wriggling about trying to push the can along on the bottom when it was noticed by Mr. A. B. Burnham. Secured easily with a fish spear, it was held up by Mr. Burnham while it was being photographed as Fig. 1 shows.

On examination it was found that the head of the fish was tightly held by the edges of the top of the can where this had been cut to get at the contents. The fish seeking food had thrust its head through this irregular jagged opening, and the hinder bones of the jaws had been caught by the edges of the metal and the fish was a prisoner to the syrup can.

Mr. Burnham noted that the can was covered with barnacles, and hence he thought that the fish had worn this long enough for the barnacle larvae to settle down and grow up. However, there is reason to think that the barnacles might have been there when the fish acquired this unique headgear. But Mr. Burnham's next point is better taken. He found that the *under side* of the can was worn thin and in places clear through, where the poor fish had pushed it along on the sandy bottom. And in the meantime the metal had worn the flesh away clear to the bone in a strip half an inch wide all around the head of the fish. Had the fish been left in the sea water a while longer there would have come about the condition of things to be recounted in the next section of this article.

It is interesting to note that this codfish weighed 15 pounds (the length is not given) and was seemingly fat and well-fed. The fish must have managed to feed (probably) on small crustaceans which would go into the can seeking food for themselves, only in turn to become food for the cod. To make this matter easier of belief, I can state that a few mouthless but fairly well-fed fishes have been described by scientific men. These must have gotten their food through the gill-openings.

A Codfish with an Iron Ring

The *Boston Herald* of July 27, 1932, published this interesting item:

> A 20-pound cod with a band of metal round its body was caught by the schooner *Elk* in South Channel and brought yesterday to the Fish Pier. The band, which may have come from a draw bucket such as firemen use, was in fair state of preservation. The fish was three feet long.

[1] The Scientific Monthly, December, 1937.

—*Photograph by courtesy of Field and Stream*

FIG. 1. A CODFISH IN AN IRON MASK.

ITS HEAD, THRUST INTO A TIN CAN, HAD BEEN CAUGHT BY THE CUT EDGES OF THE CAN AND HELD FAST.

When Mr. F. E. Firth, a U. S. Bureau of Fisheries man, stationed at the Boston Fish Pier to gather biological data, read this account he went into action. For two days he chased this fish, finally got it and had photographs made. One of these is shown in Fig. 2. At that time Mr. Firth had not got as closely in touch with the Department of Fishes of the American Museum as he has since become, so the fish was not sent to us here. It was large, Mr. Firth had no place to keep it and, as it was not in the best condition, after it had been photographed, measured and weighed, it was thrown away.

Mr. Firth's notes on this fish read as follows:

> This codfish measured 36 inches long over all, and weighed 12 lbs. dressed. It was caught from the schooner *Elk* on a line trawl about 55 miles S. S. E. of Highland Light, Cape Cod. The metal band was the top ring (cut edge) of a gallon can. The action of the salt water had rusted away all of the can but the ring. This was around the fish's neck, in front of the pectoral fins, cutting into the pelvic fins (which were nearly cut in two), and it had made a slight groove in the dorsal part of the body.

In the case of this codfish, there is every reason to believe that we have here the last stage of which the first is described in the preceding section and shown in Fig. 1. The sides of the iron bucket or can had rusted away, but the rim, largely made up of other metals in the solder, had resisted corrosion.

This is surely an extraordinary phenomenon. That the band does not make a tight fit on the cod (Fig. 2) is due to the fact that the fish had been dressed, thus considerably reducing its girth. That the fish had carried the ring for some time is attested by the data above set out and also by the further fact that there were some hydroids growing on the ring as shown faintly in one of the photographs sent to me by Mr. Firth. These, when newly out of the water, were from one to five inches long, and must have been on the ring certainly weeks and possibly months.

The Shark with the Iron Ring

Since this article was written my attention has been called to an item in a Nova Scotia newspaper reciting that early in October, 1936, Mr. Arthur Perry, of Roseway, Nova Scotia, had captured a ringed shark. After some correspondence, I got in touch with Mr. Charles D. Hagar, of Roseway, who has talked with Mr. Perry and who has courteously communicated the following facts to me.

Mr. Perry had set his herring net at

—*Photograph by courtesy of F. E. Firth*

FIG. 2. A CODFISH WITH AN IRON RING ABOUT ITS NECK.

IT TOO HAD SHOVED ITS HEAD INTO A TIN CAN, ALL OF WHICH HAD RUSTED AWAY BUT THE RIM MADE OF SOLDER.

the entrance of Shelburne Harbor, Nova Scotia. One morning on going out to "fish" this net, he found caught in it a mackerel shark about 5 feet long and about 4 feet in girth. This he towed ashore and when he began to cut it up he found around its body just back of the gills a stout iron hoop or ring. This being a tight fit had cut its way through the skin and this had on the upper surface healed over the ring. The metallic body was apparently the ring of a 60-pound lard bucket. Unfortunately no photograph was made.

The explanation is conjectural. Presumably a large emptied lard can had been filled with garbage and the whole thrown overboard from some steamer. The shark seeking food had thrust its head into the can and had got it caught therein, as had the fish shown in the first section of this article. Rust presently relieved the shark of the tin bucket but not of the ring made chiefly of solder. This ring must have been around the shark's neck for a long time, long enough for the shark to grow large enough for the ring to become sunk in and covered over by skin if not by flesh. I have elsewhere made record of small sharks with rubber bands around their neck-regions and of a fair-sized shark with an automobile casing around it just in front of the dorsal fin, but this is the first instance known to me of a shark with a metallic ring about its body.

A Trout with a Tin Collar

About 30 years ago Old Baldy Lake in the Rio Grande National Forest in Southern Colorado was stocked with trout, and in the year 1929 there was taken from it the remarkable specimen shown in Fig. 3. The fish was caught by Mr. W. M. Rodenbush who sent picture and account in to *Field and Stream*, the well-known sportsman's magazine.

The fish, when hooked, put up no fight —it could not with that tin collar impeding its movements. This collar consisted of the top of what was apparently a tin can. This collar had cut through the ventral side of the fish's body almost to the alimentary canal, and into the back for about a quarter of an inch. However, the fish, which weighed $1\frac{3}{4}$ pounds, seemed perfectly healthy.

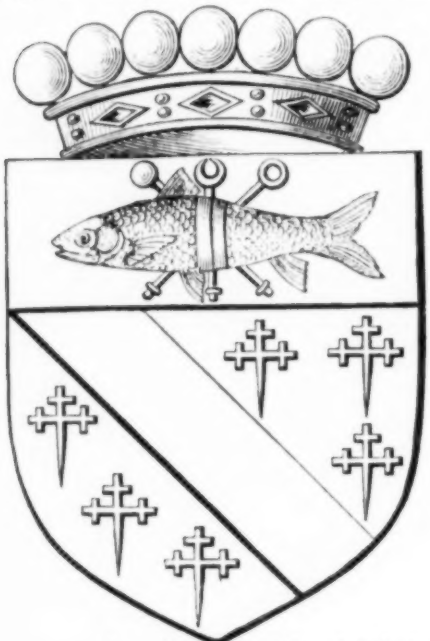
Here again the explanation of this ring is to be found in the conditions shown in Fig. 1. In nosing about for food, the fish had stuck its head into the empty tin can and its body had got caught on the jagged edges of the top where this had been cut to allow access to the contents. These edges had held fast to the body of

—*Photograph by courtesy of Field and Stream*

FIG. 3. A TROUT WITH A TIN COLLAR.

THIS IS ALL THAT IS LEFT OF A TIN CAN INTO WHICH THE FISH HAD ONCE UPON A TIME THRUST ITS HEAD.

the fish, the can had rusted away leaving the rim with the jagged edges of the top embedded in the fish's flesh. Since rusting goes on more slowly in fresh than in salt water, one must conclude that this trout had worn his ring longer than had the codfish described in the preceding section. The trout may have been hard put to it to feed when it first got caught, but, after the body of the can rusted away, it surely found conditions more



—*From Moule's Heraldry of Fish, 1842*

FIG. 4. AN HERALDIC RINGED FISH.

THE COAT OF ARMS OF VISCOUNT LAKE OF DELHI AND LASWAREE.

favorable. It certainly looks fat and well fed. But it surely is an unusual trout.

An Heraldic Ringed Fish

Fishes with rings in their mouths are not uncommon in heraldry, in armorial bearings and coats of arms, but I have discovered one coat of arms having as a part of it a ringed or banded fish. This is of Indian origin, as will now be shown (Fig. 4).

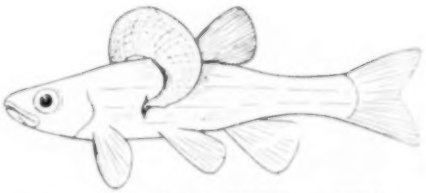


FIG. 5. A FISH WITH A SHELL NECKPIECE.

THIS WAS SEEN IN A TANK IN THE NEW YORK AQUARIUM.

The description of this coat of arms in the language of heraldry is:

> Sable, a bend between six cross crosslets fitchy argent, on a chief of the last the fish of Mogul, per pale or and vert, banded vert, and gules, surmounting the Goog and Ullum, honorable insignia, in saltier.

This is all Hindoostanee or Urdu to me —especially "cross crosslets fitchy argent," but "fish of Mogul" gives one a hint. This followed out has led to the uncovering of the following interesting information.

Under the name *Mahi Maratib*, the Indian carp, *Cyprinus rohita* (common in Gangetic waters) has long been used as a badge of dignity in India. This fish is represented on the banners of the King of Oude, but it antedates his dynasty and kingdom. It is said to have originated with the Mogul dynasty founded in India in 1206 by Chingis or Zingis Khan. The

—*From sketches by Mr. C. A. Breder, Jr.*

FIGS. 6 AND 7. HOW THE SHELL NECKPIECE ORIGINATED AND HOW IT WAS HELD IN PLACE.

THE SHELL HAD BEEN WEAKENED BY CHEMICAL ACTION ALONG THE HEAVY LINE AND THE CENTRAL PART HAD FALLEN OUT. THE FISH, THRUSTING ITS HEAD THROUGH THE HOLE IN THE SHELL, HAD GOT THE SHELL FAST TO THE SIDES OF THE BODY JUST IN FRONT OF ITS DORSAL FIN.

Yahi Maratib was chosen because the oriental legend, recited in the Koran, has it that Abraham, after sacrificing on a mountain in the land of Moriah a goat instead of his son Isaac, threw the knife into the water. This struck a carp, and to this day this is the only animal eaten by Mohammedans without its having previously had its throat cut and it blood drained off.

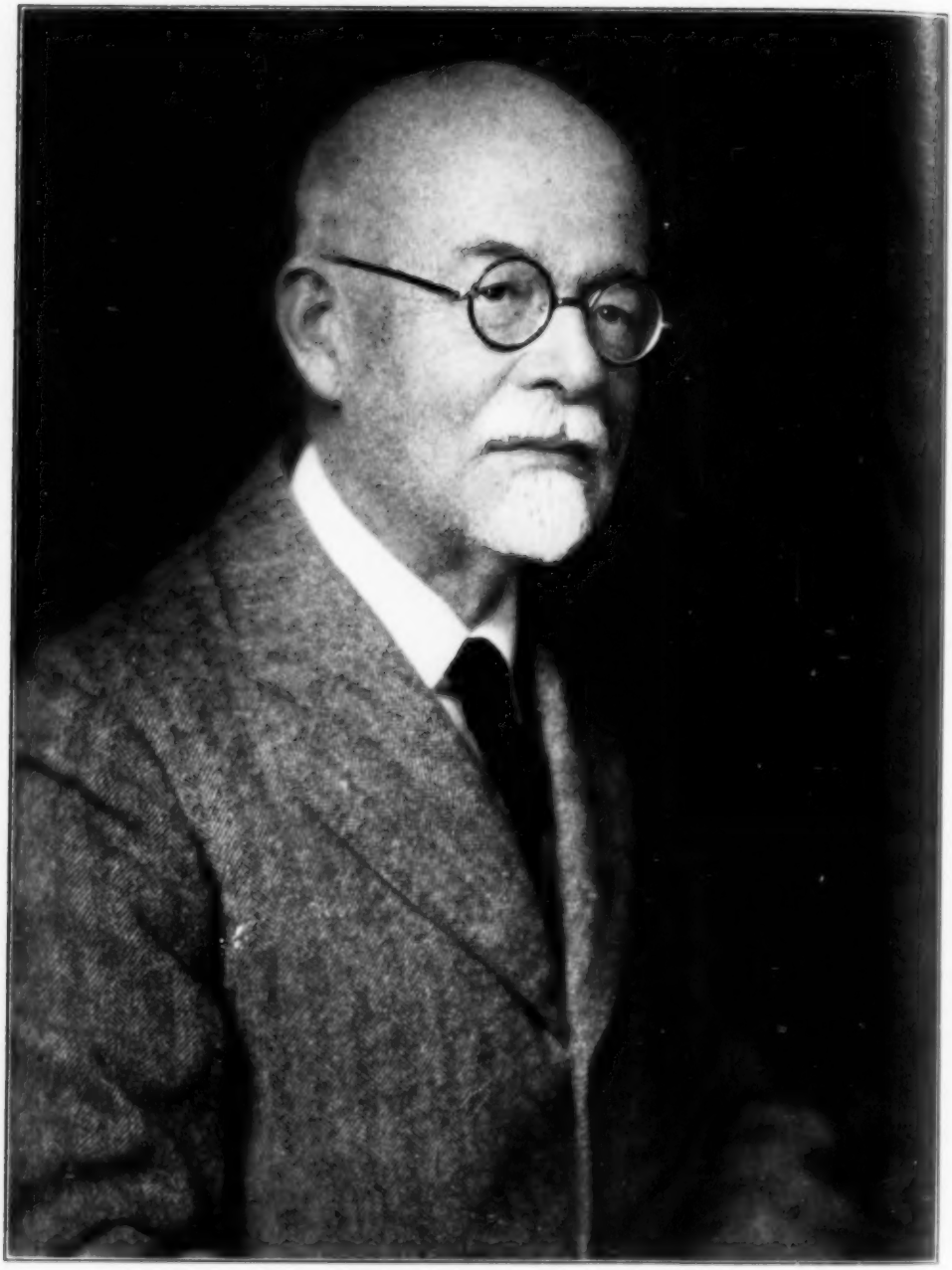
The use of this fish as a badge of dignity was revived by one of the Mogul emperors about the time of Queen Elizabeth and much later was conferred on General Gerard Lake, who won fame in India in the Mahratta War during the administration of the Marquess Wellesley. In 1803 he visited Shah Aulum (recall "Ullum" in the description of the insignia) at Delhi, from whom he received a high-sounding Persian title, which may be translated "the Victorious in War, the Savior of the State, and the Hero of the Land." Later General Lake was made Lord Lake and in 1807 was vested with the title of Viscount Lake of Delhi and Laswaree and to his paternal coat of arms was added the banded carp (Fig. 4) indicative of his Asiatic honors—probably the highest that could be given him.

A Fish with a Shell Neckpiece

Although strictly it does not belong here, yet possibly because it is *somewhat* allied to the matters presented above, and possibly because of its unusualness and interest, perhaps I may be forgiven for telling the short story of the fish with the shell neckpiece.

Early in May, 1930, Mr. C. M. Breder, Jr., of the New York Aquarium, discovered in one of the tanks a small (1¾ inch) red-bellied dace (*Chrosomus erythrogaster*), adorned with a most curious shell ornament worn on the back. This is seen in Figs. 5 and 7, lateral and head-on views of fish and ornament. Knowing my interest in such matters, Mr. Breder told me about this fish, and on May 19 I visited the Aquarium and saw what is shown in these figures. These illustrations are reproduced from pencil sketches made for me by Mr. Breder. The ornament disappeared from the fish on May 30, after about a month's wear.

The explanation is a bit difficult. Mr. Breder's suggestion is shown in Fig. 6. Among the shells at the bottom of the tank, one must have become weakened by chemical action in the region of the heavy line. Some fish in nosing about put pressure on this small segment of shell and it fell out. The same or another fish happened to push its head into the opening and the shell got caught on the body of the fish, touching it at three points (the third is the dorsal fin). Here it held until chemical corrosion on the points touching the fish's body loosened the ornament and it fell off.



EDWARD LEAMINGTON NICHOLS

IN WHOSE DEATH, AT THE AGE OF EIGHTY-THREE YEARS, EXPERIMENTAL PHYSICS HAS LOST ONE OF ITS LEADERS. DR. NICHOLS WAS PROFESSOR OF PHYSICS AT CORNELL UNIVERSITY, IN RECENT YEARS AS EMERITUS, FOR FIFTY YEARS. HIS RESEARCH WAS MAINLY IN THE FIELD OF LIGHT AND COLOR. HE DID MUCH TO PROMOTE SCIENTIFIC RESEARCH AND ORGANIZATION, HAVING BEEN PRESIDENT OF THE AMERICAN PHYSICAL SOCIETY, THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AND SIGMA XI.

THE PROGRESS OF SCIENCE

WORK LEADING TO THE AWARD OF THE NOBEL PRIZE IN PHYSICS

NOWADAYS when a physicist thinks of an atomic or a subatomic particle—be it an atom, an electron of either sign, a neutron, a proton, a corpuscle of light—he is likely to think of waves as well. He may, and often does, have only the vaguest sort of a notion or image of these waves; but he has a very definite value for their wave-length provided that he has fixed the momentum of the particle, while if he has a value for the energy of the particle he has an equally precise one for the frequency of the waves. Two by two these quantities are bound together by what may be called the "rules of correlation of particle and wave"—rules of the utmost simplicity, which are written thus,

$$p = h/\lambda, \qquad E = h\nu$$

when the customary symbols p and E are employed for the momentum and the energy of the particle, λ and ν for the wave-length and the frequency of the waves. Awareness of these interrelations, awareness of the coexistence of particles and waves connected by these equations, have been gradually growing and expanding ever since 1899, when Max Planck started the trend of thought which has culminated in these rules of correlation. Planck's rôle in the history of physics is well commemorated by the name of the universal constant denoted by h in these equations: it is Planck's constant. As Planck's name at the beginning, so the names of the Nobel laureates of 1937—C. J. Davisson and G. P. Thomson—stand at the climax of this great period of discovery: the period during which the association of waves and corpuscles, dimly and partially guessed at the start, was year after year progressively revealed as a universal principle.

During almost the whole of this twenty-eight-year period, the association was realized for light and for light alone; and during fifteen of those years it was only the second of the rules of correlation ($E = h\nu$) which was known. Any physicist who was educated in the last ten years before the war must surely remember the nervous and dubious way in which he was taught of the strange phenomena which had revived the long-buried corpuscular theory of light. These were phenomena in which only the energy of the corpuscles was apparent, and accordingly it was only the interrelation of E and ν which was grasped. It was Einstein who proclaimed most daringly the coexistence of corpuscles and waves; and it was also Einstein who in 1915 completed the correlation—completed it in so far as light, and light alone, was concerned—by discerning the other of the two rules. It frequently happens in physics that the first-to-be-discovered way to a new principle is also one of the hardest ways: and almost always it has so happened in the history which I am briefly retelling. There must be many a physicist to whom the equation $p = h/\lambda$ is already almost second nature, and who yet has never read Einstein's paper of 1915. It was the Compton effect which in 1922 made this interrelation intelligible to all.

Now that the correlation was successfully made for light, the extension to electricity and matter followed quickly. The first to suggest that the Rules of Correlation apply also to these was Louis de Broglie, in whose honor the associated waves are known as "de Broglie waves." Upon him followed Schroedinger, who applied to these waves very much the same sort of mathematical treatment as for decades has been familiar to the students of light-waves and sound-waves. By this method he assailed the great central problem of theoretical physics, the problem of the hydrogen atom. Bohr had already partially solved this prob-

DR. C. J. DAVISSON
MEMBER OF THE TECHNICAL STAFF OF THE BELL TELEPHONE LABORATORIES.

lem by imagining an electron revolving around a nucleus, and imposing certain prescriptions upon the orbits of this electron. Schroedinger now proceeded to show that if (for the sake of the argument) we dismiss temporarily from our minds the revolving electron and imagine instead its associated waves, then the stationary wave-patterns of these waves correspond to and determine the stationary states of the atom. This to this day is the accepted method of the theoretical physicist for investigating atoms and molecules, of all kinds and all degrees of complexity; and great have been its successes.

But was it not unsatisfactory to be obliged to prove these de Broglie waves by invoking so intricate and recondite a theory as that of the atom, while for light-waves there are so many and such beautiful experiments of interference and diffraction to make them obvious? It *was* unsatisfactory indeed; and we should still remain in that difficult situation, were it not for the experiments which

Davisson and Thomson were the first to perform. They *did* achieve obvious and spectacular diffraction of the waves associated with electrons, similar to the diffraction of light of corresponding wave-length. "Light of corresponding wave-length" signifies x-rays: electrons of convenient speeds are correlated, by the rule aforesaid, with waves as short as those of x-rays, while de Broglie waves of wave-lengths like those of visible light correspond to electrons so slow-moving that technical difficulties impede the experiments. They achieved this diffraction just as that of x-rays is achieved: by employing crystals as diffraction-gratings. The beam of free negative electricity, consisting of a stream of electrons of uniform speed associated with de Broglie waves, was projected against a single crystal in Davisson's experiment—against a very thin polycrystalline film

PROFESSOR GEORGE PAGET THOMSON

DEPARTMENT OF PHYSICS, IMPERIAL COLLEGE OF SCIENCE, UNIVERSITY OF LONDON. PROFESSOR THOMSON IS THE SON OF SIR J. J. THOMSON, HONORARY PROFESSOR OF PHYSICS, UNIVERSITY OF CAMBRIDGE, AND MASTER OF TRINITY COLLEGE.

KING GUSTAV OF SWEDEN

PRESENTING THE NOBEL PRIZE TO DR. DAVISSON. KING GUSTAV, WHO WILL BE EIGHTY-ONE YEARS OF AGE IN JUNE, IS KNOWN FOR HIS SKILL IN TENNIS TOURNAMENTS. LIKE HIS DISTANT COUSIN, KING CHRISTIAN OF DENMARK, AND OTHER MEMBERS OF THE BERNADOTTE FAMILY, HE IS VERY TALL, IN MANNERS AND APPEARANCE "EVERY INCH A KING."

of metal in Thomson's. Had it not been for the waves, the electrons would presumably have dispersed in every direction in a chaotic outrush as soon as they encountered the thickly set atoms of the crystals. The waves, however, were guided, by the regularity of the crystalline lattice, into each of a limited number of sharply defined directions according to the classical laws of diffraction; and they in their turn guided the electrons. Davisson and Thomson provided, for the waves associated with electrons, evidence as clear and striking as that which the world had long since received and accepted as proof for the waves of light. Also their measurements substantiated the rule of correlation $p = h/\lambda$ for the electrons and their waves. Also they initiated a new and ever-expanding field of research, the investigation of the structures of thin films by use of the diffraction of electrons: but this is another story.

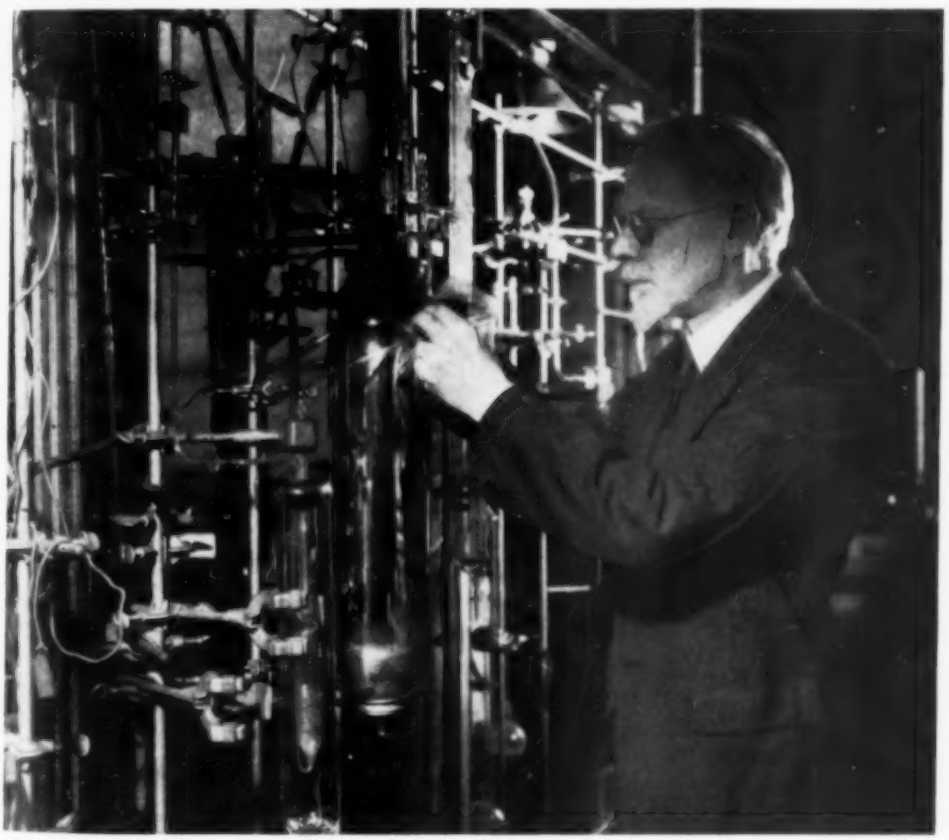
KARL K. DARROW

THE PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY

THE election of Professor Charles A. Kraus, director of chemical research at Brown University, as president of the American Chemical Society has been announced. As head of a group of some 20,000 chemists, Professor Kraus will take over the office on January 1, 1939, succeeding Professor Frank C. Whitmore, of the Pennsylvania State College.

Dr. Kraus, who has devoted his life to science and to its relationships with human welfare, will direct a broadened program of chemical research in the new laboratory recently erected at Brown University at a cost of $500,000 which will be opened next September.

Professor Kraus is best known in the world of industrial chemistry for a research which led directly to the commercial production of the "high test" or ethyl gasoline, familiar to every motorist. His investigations into anti-knock fuels were carried out in cooperation with one of the leading companies. He is also known for the development of the first method for making vacuum-tight seals between ordinary glass and fused quartz. He was last year awarded the Theodore William Richards Medal by the Northeastern Section of the American Chemical Society for his work on the theory of solutions, especially in connection with



PROFESSOR CHARLES A. KRAUS
PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY.

ammonia. In 1935 the Chicago Section of the society presented to him the Willard Gibbs Medal for his work in the same field. Two years earlier, the Nichols Medal of the New York Section of the American Chemical Society was awarded to him for his work on non-aqueous solutions. These investigations have demonstrated that certain metals are capable of forming solutions with liquid ammonia, which at high concentrations behave as metals. At low concentrations the solutions are salt-like and conduct electricity electrolytically. With his graduate students, Professor Kraus has so widened the horizon of knowledge of liquid ammonia solutions that to-day more is known about liquid ammonia than about any other solvent except water. He has also extended scientific knowledge of the field of metallo-organic compounds, particularly those of tin, germanium, silicon and boron. He has brought to light numerous new substances of scientific interest, including alloys that behave like salts and metallic compounds that contain carbon and hydrogen.

Dr. Kraus received the B.S. degree from the University of Kansas in 1898 and the degree of Ph.D. from the Massachusetts Institute of Technology in 1908. In the meanwhile he had been fellow of the Johns Hopkins University, instructor in the University of California and assistant in the Massachusetts Institute of Technology. He became professor of chemistry and director of the chemical laboratories at Clark University in 1914 and during the war directed research at the university for the Chemical Warfare Service, acted as consulting chemist for the Federal Bureau of Mines, and from 1922 until 1924 was in charge of the Fixed Nitrogen Research Laboratory. He first became associated with Brown University as a lecturer in 1923 and the following year was appointed professor of chemistry and director of chemical research.

THE NEW HEALTH CENTER BUILDING IN BROOKLYN

The new Red Hook-Gowanus Health and Teaching Center, erected at a cost of $250,000, at 250 Baltic Street, Brooklyn, the eighth city-built and Public Works Administration-financed health center building to be opened in New York City during 1937, was dedicated by the Health Department on November 30. The structure is the second unit in New York City's cooperative program with the five medical schools in the city for utilizing district health work as a training ground for medical students, Health Department personnel and other public health workers, in preventive medicine and public health administration.

The teaching program in the Red Hook-Gowanus district is conducted in cooperation with the Long Island College of Medicine, in close proximity to the new health center. The medical school's department of preventive medicine and community health, under the direction of Dr. Alfred E. Shipley, is housed in the building, which has facilities for maintaining a public health service for the community, with emphasis on preventive medicine and health education. Dr. Leopold Rohr is director of the center.

Quarters for the medical school are provided on the fourth floor. These include offices, a faculty room and laboratory and lecture and study rooms for students. Health Department personnel, including the district health officer, heads of clinics and supervising nurses, participates in the teaching program for medical students. The teaching of preventive medicine and community health under Dr. Shipley and his staff is begun in the first year and extended into the clinical years, in this way emphasizing the integration of the practice of preventive and curative measures. Social and medical practices

THE NEW RED HOOK–GOWANUS HEALTH AND TEACHING CENTER

for the control and prevention of infectious diseases are considered, with particular reference to the physician's rôle in applying these measures in his community. The instruction culminates with a four-week clerkship for senior medical students at the health center. Approximately ninety fourth-year students of the Long Island College of Medicine are divided into groups of ten for the clerkship course. Thus the senior medical students serve an apprenticeship in the tuberculosis, venereal disease and child hygiene clinics; observe dental hygiene procedures and attend conferences of local physicians, cooperating agencies

and civic and medical groups, for a broader understanding of community health problems.

The Red Hook-Gowanus Health and Teaching Center is of white brick and stone construction, with basement and four stories. The building occupies a site fronting 75 feet on the south side of Baltic Street, between Court and Clinton Streets, and has a depth of 100 feet. The main entrance on Baltic Street leads into a spacious lobby. On the first floor are the maternity and child health and the dental and social hygiene services and conference and waiting rooms. On the second floor are the tuberculosis and eye services, quarters for the establishment of a parasitology clinic, the district office of the Brooklyn Bureau of Charities and quarters for the United Jewish Aid Society. On the third floor are the district health officer and administrative staff, Department of Health and Brooklyn visiting nurses, health education staff and a conference room for physicians of the district. The fourth floor houses the Long Island College of Medicine and the district office of the Brooklyn Bureau of Charities. The basement of the building includes an auditorium, exhibit rooms, a nutrition department, a staff kitchen and lunchroom, a staff emergency room and boiler and storage rooms.

New York City's district health program provides for the organization of thirty health center districts by 1945 or one administrative unit to serve each 250,000 population area of the city's approximately 7,500,000 people. Since last June, new health center buildings have been opened in the East Harlem, Central Harlem and Lower West Side districts in Manhattan; in the Mott Haven section of the Bronx; in St. George, Staten Island; in Astoria-Long Island City, Queens, and in the Williamsburg-Greenpoint and Red Hook-Gowanus districts, Brooklyn. Of these, the Red Hook-Gowanus and the East Harlem buildings, the latter in conjunction with New York Medical College and Flower Hospital, are combined health and teaching centers. A third unit in the health and teaching program is being built and will be opened this year. This is the Kips Bay-Yorkville Health and Teaching Center at 411 East 69th Street, Manhattan, which will be operated in conjunction with the New York Hospital-Cornell University Medical College. Building plans are under way for the Lower East Side Health and Teaching Center, East 25th Street and First Avenue, in cooperation with the New York University College of Medicine, and the Washington Heights Health and Teaching Center, West 168th Street and Broadway, in cooperation with the College of Physicians and Surgeons, Columbia University.

Although the new health and teaching center buildings will be located in only five of the city's thirty health districts, the benefits obviously will be city-wide. The medical colleges will be able under this program to offer their students courses in public health practice and preventive medicine, which will be closer to the realities than ever before. Aside from the gain which this training will record in public health administration, there should be immeasurable enrichment in the field of private medical practice. Medical students who have had the training which the health and teaching centers provide and who will ultimately go into private practice, will be fortified with more extensive experience in preventive medicine for use in their daily work than has heretofore been the case.

The health and teaching program which New York City is launching is the product of the best thought of leaders in the fields of medicine and public health administration. Development of the program has had the active support and

leadership of Mayor Fiorello H. LaGuardia, and realization of the undertaking would not have been possible except for the understanding, effort and assistance of the deans and other officials of the cooperating medical schools. This is another step forward for the New York City Department of Health, as well as for the medical profession, in their mutual efforts to serve the community.

JOHN L. RICE,
Commissioner of Health

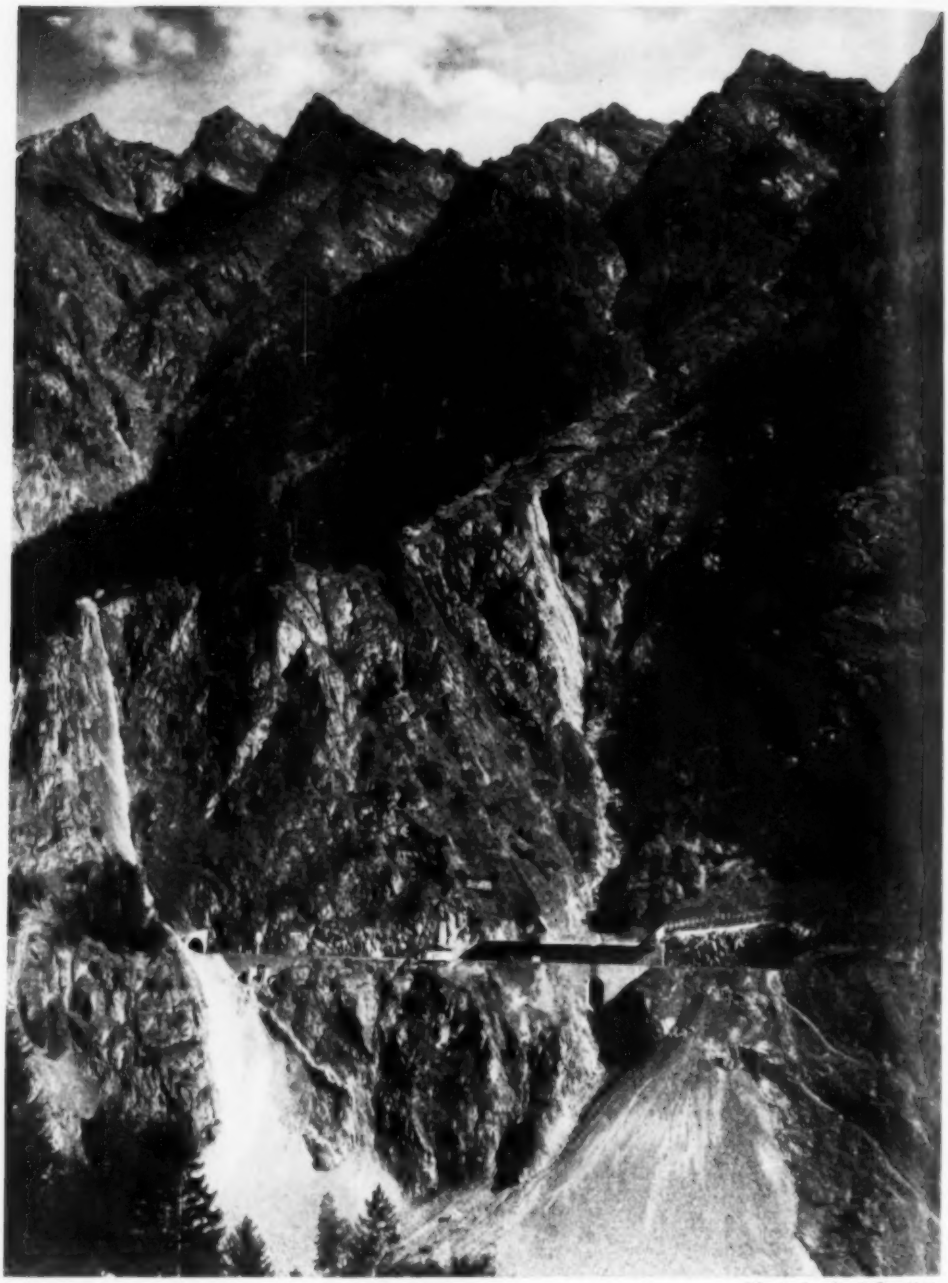
AVALANCHES IN THE SWISS ALPS

To the man in the street an avalanche is an avalanche. Even to the dictionary it is simply "a large snow slide." However, there are different kinds of avalanches, and they vary according to the weather conditions that produce them. They are generally classified into ground and dust avalanches.

—Photo by Erika Nikles

A WETTERHORN AVALANCHE

WHICH DESCENDED RECENTLY NEAR GRINDELWALD IN THE BERNESE OBERLAND, SWITZERLAND.



—*Photo by G. Schneiter*

THE LÖTSCHBERG RAILWAY

IN SWITZERLAND, WHICH CONNECTS THE BERNESE OBERLAND WITH THE SIMPLON ROUTE IN THE VALAIS, FEATURES NUMEROUS PROTECTIVE AVALANCHE GALLERIES ON ITS SOUTHERN SIDE.

—*Photo by Marga Steinmann*

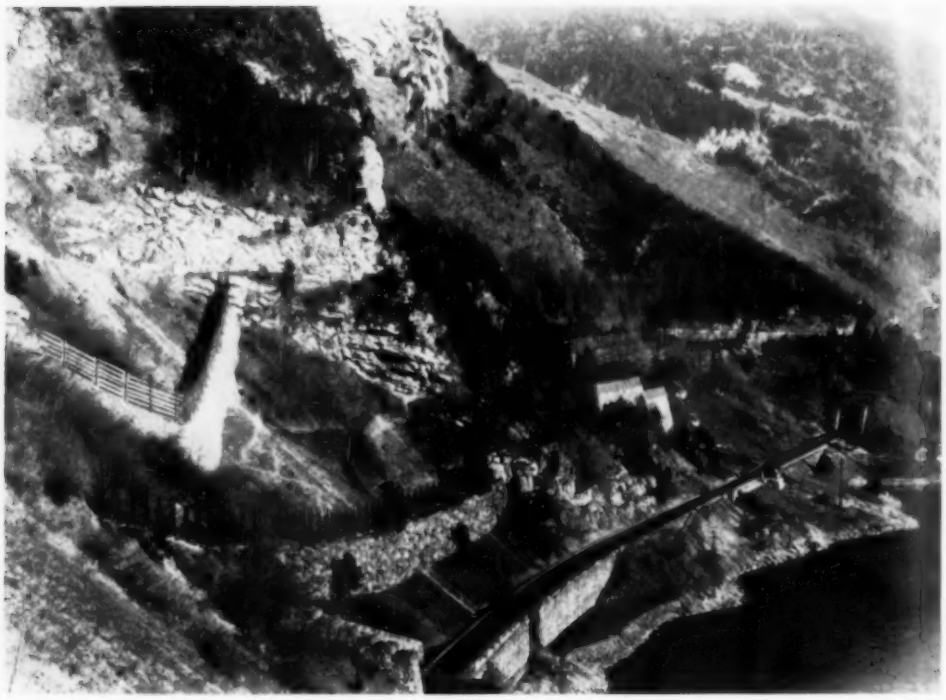
A JUNGFRAU AVALANCHE

IN THE BERNESE OBERLAND, SWITZERLAND. ONLY ON RARE OCCASIONS DO PHOTOGRAPHERS HAPPEN TO BE ON HAND WHEN THIS CATARACT OF POWDERY SNOW MAKES ITS SWIFT DESCENT FROM THE MOUNTAIN.

Of the ground avalanches there are some that affect the actual surface of the land over which they travel but slightly; others, however, dig deep into it, and furrow it and maul it like gigantic ploughs. Both kinds will sweep away the rocks, trees and houses that happen to be in their path. When the so-called "Black" avalanche has finished its work of devastation it is an ugly-looking accumulation of dirt, tree-trunks and mud-colored snow. The "White" variety, as its name implies, though equally destructive to hillside, forest and mountain chalet, comes to its rest with an untarnished, glittering surface.

Dust avalanches are the most dreaded, for while the ground avalanches fall according to well-known rules, at specific times of the year, the dust avalanches are erratic in their movements. Dust avalanches consist of dry, powdery snow which is susceptible to the slightest vibration. Loosened from the vertical face of the cliffs to which it has been clinging, it begins to run down like grains of sand, growing as it falls, by drawing down with it other beds of snow. It is like a snowy waterfall, bursting out suddenly from the mountain. Swiftly it gathers speed and with ever-increasing power and a deafening roar, caused by the tornado-like wind which always accompanies an avalanche, it uproots trees, crushes chalets and whatever happens to be in its course. At the end of its path of destruction it covers the ground with a bed of snow from thirty to fifty feet deep.

Avalanches are a regular feature in certain alpine districts when the warm



THE SWISS FEDERAL RAILROADS

HAVE CONSTRUCTED VERITABLE FORTIFICATIONS ALONG THE ST. GOTHARD LINE NEAR FLUELEN AT THE SOUTHERN EXTREMITY OF THE LAKE OF LUCERNE.

breath of spring softens and loosens some of the old frozen snow. These so-called "melting avalanches" invariably follow certain tracks which are strongly embanked like the course of a river with branches and timber. In order to be out of the avalanche path, the human dwellings in such sections are generally huddled closely together, and alpine highways and railroads are carefully protected by scientifically constructed galleries.

While the average visitor will probably never experience the thrill of observing an avalanche in its descent from a near-by point of vantage, alpine climbers are more likely to encounter this fortunately not frequent peril. Long experience and careful observation of this phenomenon in nature have enabled the Swiss people to meet it with adequate measures of precaution and defense.

MARIE WIDMER